THE HYSTERICAL BACKGROUND of RADIO

R·P·CLARKSON

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By

R. P. Clarkson

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To

THE AMERICAN

RADIO RELAY LEAGUE

In Appreciation

of Its Services to Radio

"If this you can denie,
then seeme to make reply,
And let the painefull sea-man judge,
the which of us doth lye."

NORMAN: "Lodestone's Challenge."

AUTHOR'S PREFACE

This book contains no mathematics and is not technical in any sense. It is written for the general public and more for entertainment than instruction, but those who are deeply interested in technical radio will find herein many leads which followed to their source will prove valuable. I have given no bibliography for the good reason that readers to whom it would be of interest can readily trace all sources from the names of the 362 men whose work is mentioned. For the general reader the list of those who have contributed permanently to the background of radio is nearly complete but to the technician the absence of such names as Kirchoff, Steinmetz, Planck, Lieben, Braun, Reisz, Vreeland, Poincarê, Rutherford, Grotthuss, Clausius, Kohlrausch, Rayleigh, Poynting, Eccles, Joly, Oudin, Boys, and others will be readily understandable as due to the popular character of the work.

Obviously this is largely a compilation. My first thought was to gather together the threads of discovery wherever I could find them and weave them loosely into a sort of radio tapestry that all could understand. But I have accomplished the same end, I hope, in setting forth the progress of the idea and apparatus of communication, a summary of the idle wanderings of the human intelligence in the electrical field. No reader can fail to be amazed at the large part played by "Lady Luck" and the total lack of direction that has

always been so manifest. We can, of course, by choosing items here and there manage to unveil a systematic progress but it is only by giving importance to events that had no importance at the time and weren't remembered. There has been no system but a flitting about from limb to limb, all hands flocking to any point of interest uncovered by some lone worker and then, as a rule, turning their backs on the first man.

Men started out to philosophize, to think without experimenting. They ended up by experimenting without thinking. The isolated experimenter has always grasped the prize. Organized research, except perhaps in the case of Michael Faraday, who hardly belongs under this heading, has not produced a single outstanding discovery to compare with the locomotive, the steamboat, the telegraph, the telephone, the steam engine, wireless, the vacuum tube, the aeroplane, the submarine, the automobile, the screw propeller, the moving picture, the telescope, the camera. Every one of these is the product of the garret, not of the laboratory. The individual working alone makes the long leaps ahead. Organization merely fills in the gaps, and does that under compulsion. The inertia of the human mind must be enormous!

Maybe that is what Mr. Henry Ford had in mind when he said, under oath, that "history is bunk."

Anyway, here's the bunk!

R. P. Clarkson

Mechanics Institute,
New York City,
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PART I

MYTH AND MYSTERY

The story of amber and of the magnet from ancient days, through the times of Columbus, William Gilbert, Gray, Dufay, Musschenbroek, and Nollet to the discoveries of Benjamin Franklin.

CHAPTER I

GARLIC AND DIAMONDS

> "We remember the fish which we did eat in Egypt freely; the cucumbers, and the melons, and the leeks, and the onions, and the garlick."
>
> —NUMBERS XI:5

GARLIC, says the dictionary, is a hardy bulbous perennial of the same genus as the onion, and similar authority suggests that a perennial survives year after year. It is with the perennial nature of garlic that our story has to do. Not that form of survival so evident to one who travels in the crowded chariots of the great metropolis but a survival in what we may be pleased to term the literature of science.

One shudders at the mention of the word, but the true historian must give even the devil his due. Garlic is important in any history of radio or even in this tale of laughter and of tears and in spite of its relation to the onion, it did not cause the tears. As we shall see, it did sometimes cause a sailor's death or worse than death,

the agony of having "the hand which he most uses" spiked to the mast or "principal timber of the ship" there to remain until he himself tore it free. What price garlic!

For more than fifteen hundred years this garlic myth survived. Even as late as the seventeenth century, when England had passed through all the glories of the Elizabethan age, the philosopher Ross still had his doubts. "I cannot think," he remarks, "that the ancient sages would write so confidently of that which they had no experience of, being a thing so obvious and easy to try; therefore, I suppose they had a *stronger kind of Garlick* than with us."

What was this myth? Why this speculation and even doubting? Was garlic unfit for food? Why, no! Then and now only the social phase was in question. It was the odor of garlic which was observed. Its potency was such, if we believe those "ancient sages," that it destroyed magnetism. The attractive power of the compass passed away as soon as garlic was smelled in the offing, just as it would in the proximity of diamonds. Ordinarily, of course, diamonds were not a part of the sailor's garb in those pre-Volstead days but he sometimes did dine on garlic. Hence, under ancient sea laws it behooved the skipper to prohibit anyone in charge

of the compass or of the lodestone from eating either onions or garlic which "not only may deprive the stone of its virtue, but, by weakening it, prevent them from perceiving their correct course."

In literature this myth began with Pliny, that famous Roman writer whose zeal for scientific research led to his death by suffocation in the great eruption of Mount Vesuvius in 79 A.D., made ever memorable in the description of it by Pliny the younger, nephew of the one who perished.

The garlic myth passed through the learned treatises of all philosophers as Ptolemy, Plutarch, Langins, Marbodæus, and many Arabian sages, too. In 1544 when the great teacher and theologian Philipp Melanchthon gave to the waiting world in Wittenberg, his treatise on Physics, the potency of garlic was the only phenomenon concerning the magnet about which this fellow laborer with Luther seems to have been informed.

Pietro of Abano denied the fact at the end of the twelfth century, about the time of Richard Cœur de Lion, and Cardan attempted to refute it in 1550. Baptista Porta ridiculed it in the "Magia Naturalia" (1589) but not until 1646 did it even stagger. Its deathblow was dealt by Thomas Browne, who says, in his "Enquiries into

Vulgar and Common Errors," "for an iron wire heated red-hot and quenched in the juice of the garlick doth notwithstanding contract a verticity from the earth and attracteth the southern point of the needle. If also the tooth of lodestone be covered and stuck in garlick, it will notwithstanding attract; and needles excited and fixed in garlick until they begin to rust do yet retain their attractive and polary respects."

Fortunately for the good doctor's peace of mind, it was the wire and not the stone and needles that he heated when the test was made, for magnetism can be destroyed by heat as Fra Paolo seems to have discovered less than fifty years before.

Browne stands out as an iconoclast. He had the temerity to seek evidence to prove what he said at a time when it wasn't being done. Science had not yet become in fashion. Folly had not put "her shoulder to the load which reason could not move." Men merely speculated on each other's speculations. Fear gave wings to speculation which turned to superstition in an age when pirates infested the seas and knowledge of the earth was not profound.

The compass pointed the way to either life or death. This humble forerunner of the Radio was and is important. It seemed mysterious,

occult. Tampering with the compass needle or with the precious stone on which the needle was rubbed to get its virtue, might well bring the ship to wreckage on unknown and hostile shores, an easy prey from land or sea. It is hardly surprising that a breath "fit to knock a man down" in these dentificial days when even your best friend won't tell you, was then thought powerful enough to deal a body blow to lodestone, and be the cause of that terribly cruel sea law of Wisbuy quoted at the beginning of this chapter.

We must remember, too, that no one knew what a magnet was, how it became magnetic, how it retained magnetism, nor yet what principle, if any, was involved.

> "The lodestone is the stone,
> the only stone alone,
> Deserving praise above the rest,
> whose vertues are unknown,"

sang Robert Norman, an instrument maker of Bristol, England (1576), who gave us knowledge of the magnetic dip.

The lodestone had come down from almost the dawn of history, perhaps. Its antiquity is hard to judge through contradicting evidence, but we know that it gave the first impetus to philosophic thought. To Thales, that brilliant mixture of Phœnician and Hellene, six hundred

years before the Christian era, the lodestone had a soul and somehow the soul produced motion in the iron it drew to itself, if we are to believe Aristotle, who frankly derived all he knew about Thales from hearsay.

Plato in the *Ion* two hundred years later makes Socrates agree with this concept of Thales. Socrates speaking: "There is a divinity moving you, like that in the stone which Euripides calls a magnet, but which is commonly known as the stone of Heraclea." Thus was science in its early days.

But this conception of a soul in the magnet is as nothing at all compared to the garlic theory or to that other idea ascribed to Aristotle (384 B.C.) in the probably spurious "Book of Stones" where there is mentioned a flesh magnet which, once attached to the body, can't be removed "without tearing with it the flesh, although, in the latter, not a drop of blood will be found."

This mild rumor grows until by 1569 we find Fenton in "Certaine Secrete Wonders of Nature" telling of a kind of stone "which draweth unto it fleshe" so strongly "that it hath power to knit and tie together two mouthes of contrary persons and drawe the heart of a man out of his body without offending any part of him," which, as anyone will admit, is a fairly large order but

a good trick if he did it. It seemed time for Mr. Browne to call a halt and while refuting the garlic he exclaims that the "fleshe stone" stories are "of that monstrosity that they refute themselves." Apparently he never saw a tabloid newspaper!

The diamond myth dates from St. Augustine, a restless erring priest, who, only four centuries after Christ, used the mystery of the magnet as an example in defense of miracles, pleading against the idea that miracles should be explained by any form of human reasoning. In his books he tells all that was known about the magnet at that time and tries to distinguish clearly between what he has *seen* and what he has *read*. He has read "when a diamond is laid near it (the lodestone), it does not lift iron; or, if it has already lifted it, as soon as the diamond approaches it drops it." At the last he confesses that he knows not by what imperceptible potion the lodestone "refuses to move straws and yet snatches the iron."

This is the first notion of a possible difference between the attraction of a magnet for iron and the attraction of amber when rubbed, for straw or chaff of any kind, a distinction between magnetism and what we now know as electricity. Such possible difference was soon forgotten.

To almost everyone up to about 1600, it simply was taken for granted that these two were the same phenomenon. *Nevertheless, with those words the science of electricity began.*

Before the end of the sixteenth century we find the Italian philosopher, John Baptista Porta, setting forth that iron rubbed by a diamond would become magnetic. This assertion stood until Dr. William Gilbert in England tested it before many witnesses by the frictional effect on iron of some seventy-five diamonds. After this expense without results what Gilbert publicly said about Mr. Porta was indeed a mouthful. Contemporary estimates are that the physician of Queen Elizabeth spent about $25,000 on his magnetic experiments, but not all were as fruitless as this.

The theories that the presence of a diamond killed the lodestone and that iron rubbed by a diamond became a magnet had both been shown to be false by the simple, but almost unheard-of, expedient of trying them. There still remained the statements accredited to Cardan and Fracastorio that diamond when rubbed would attract chaff just as amber does under the same circumstances and just as your fountain pen when rubbed briskly on your coat sleeve will attract dust and small bits of paper.

Gilbert, in fine rage, proclaimed these two eminent philosophers to be nothing but "chattering barbers," an epithet which shows how the face scrapers of that age were regarded by the court at a time when they were also dentists and vociferously contesting their right to practice medicine as well. Imagine that!

However, Gilbert, after the previous experiment, was well supplied with diamonds and no doubt he tried rubbing them. He found that they could be electrified but gave no credit to his predecessors for the idea. He simply went on to one of the major discoveries which makes him famous in a world of charlatans.

He found that almost anything he tried, except the metals, could be electrified by rubbing. So he compiled a huge list of "electrics" including true jewels and paste imitations, sulphur and sapphire, carbuncle and crystal, sealing wax and rock salt, alum and resin. It was Gilbert who gave the name "electric" to this effect but Robert Boyle's "On the Mechanical Production of Electricity" published at Oxford in 1675 is the first work to use the term "electricity."

It was plain to Gilbert that this electric property pervaded all matter, and he lost no time in drawing down the wrath of heaven on the whole theological and philosophical tribe with their

doctrine of amber souls and occult influences. More important, perhaps, than this vituperation were the arguments which Gilbert developed from his discovery in support of the theory ascribed to Copernicus, but not original with him, that the earth revolved around the sun.

The hope of some such result was, in fact, the purpose of Gilbert's experiments, rather than any desire on his part to discover new phenomena in the field of electricity. And even in Gilbert's time at the beginning of the seventeenth century, when the *Mayflower* was soon to set sail for the New World, the opinion of the Church was arrayed against this heretical doctrine. To the Fathers and to the faithful for many years to come, the earth was the fixed, immovable center of the universe about which all heavenly bodies moved.

Gilbert stood squarely between the new philosophy and the old, and like Mr. Munsey's well-known combination of newspapers, strived to retain the best features of each. He is close to the dividing line between the decline of military and clerical power and the upward trend of civilization in science and industry and was an able preface to the much-overrated Francis Bacon, who, though ever disagreeing with some work of Gilbert's, respected much and praised little of it but found it all worthy of perusal, although

to Bacon's disgrace he endeavored to conceal Gilbert's later work.

In some unaccountable way the garlic myth survived Gilbert more than forty years. One regrets that the richness of his vocabulary (rather than that of the mild Browne) could not have been turned toward this odoriferous matter.

When Gilbert died in November, 1603, but seven months after his royal mistress and incidentally in the same year that Shakespeare created Hamlet, the world of science knew there was some sort of a distinction between electricity and magnetism, between the rubbed amber and the lodestone. It had only two pieces of apparatus from two thousand years of research. These were the compass and the electroscope of Gilbert's, this latter being a straw pivoted like a compass needle to indicate the approach of a charged body in the same manner as the compass does a magnet.

Both of these instruments were of infinite importance in the centuries which followed. Both are in use to-day in substantially their original form and together they are the basis of all electrical measuring instruments.

William Gilbert, physician to Queen Elizabeth, is the father as well as the godfather of electricity.

He is, perhaps, the grandfather of Radio!

CHAPTER II

MAHOMET'S COFFIN AND THE MAGIC MOUNTAINS

"Canst thou send lightnings, that they may go, and say unto thee, here we are?"

—JOB XXXVIII: 35

THE garlic and diamond theories are typical of the superstitions which spread at a time when manuscripts were rare and knowledge was not diffused beyond the confines of the little group or town where it originated. For centuries those who dared experiment dared not tell about it too widely. It was much safer to speculate and enlarge upon some twice-told tale which travelers carried here and there.

But we have seen how the diamond myth led ultimately to Gilbert's great discoveries. Another story which Pliny gives us had even a stranger result at the hands of the same philosopher, this time a poem written two hundred years before Pliny by one Nicander. It concerns the shepherd Magnes, who kept his flocks on

Mount Ida and while strolling about found the nails (sic) of his shoes and the ferrule of his staff suddenly adhering to a stone subsequently called after him the "Magnes" stone or magnet.

This legend grew. Ptolemy in the second century in his geography made the rock a mountain in Southern China and the shoe nails became the nails of a ship. Then he blithely tells us that "ships which have iron nails are stopped" by the magnetic attraction of the mountain on the nails, of course, "and that is why they are put together with wooden nails, in order that the Heraclean stone which grows there may not attract them."

St. Ambrose puts the mountains in the Persian sea. A Chinese author, So Soung, in the eleventh century, strangely enough, repeats the tale with Ptolemy's location. It appears in Dutch, Danish and Norse epics with varying locations for the mountains, and even in the Arabian books, reaching its finished form in the History of the Third Calendar in those fantastic stories of the "Arabian Nights," brought to Europe from Syria about 1584. Here Agib affirms that all the nails and iron in the ships of his fleet flew to the mountains "where they fixed, by the violence of the attraction, with a horrible noise."

When the compass became known, it was in-

evitable that sooner or later these magic mountains would be considered the attracting power which caused the constant pointing of the needle to the north. Such connection first appears in the thirteenth century verses of an Italian poet, Guido Guinicelli (Benjamin's translation):

"In what strange regions 'neath the polar star
May the great hills of massy lodestone rise
To turn the quivering needle to the Bear
In splendor blazing in the Northern skies."

Meanwhile, another yarn of Pliny's had suffered many changes. He ventured to assert that the architect Timochares began to erect a vaulted roof of lodestone in the Temple of Arsinoë at Alexandria so that the iron statue of this delightful queen, who murdered her stepson and married her own brother, might hang as if suspended in the air. Considerable argument seems to have arisen whether or not the job was finished, but the venerable Bede in 703 A.D. while affirming that the earth is spherical says, among other things having nothing to do with the subject, that the horse of Bellerophon on the Isle of Rhodes was similarly suspended in mid-air.

Even before this the story was applied to a statue of Cupid in the temple of Diana at Ephesus, that wonder of the ancient world destroyed

by fire in 356 B.C. but afterwards rebuilt in lesser glory. Maimonides toward the end of the twelfth century mentions an image of the sun suspended in a Babylonian temple by magnets and alleges that our Biblical friend Jeroboam suspended the well-known Golden Calves in the same way. St. Augustine, St. Isidore, and Cedrinus, among others, all agree that somewhere there was such a suspended image.

To-day we have the same yarn in the story of Mahomet's coffin suspended between earth and sky at Mecca. As Gibbon says, there are two main objections to this legend,—(1) Mahomet isn't buried at Mecca (he fled from Mecca to Medina in 622 A.D.), and (2) his tomb has been visited by millions and is on the ground. Otherwise it is a good tale.

A curious survival of a similar thought in literature as late as 1726 may be found in "Gulliver's Travels." The third voyage is to Laputa, the island that Swift pictures as floating in space, supported and moved about by virtue of the magnetic action of a gigantic lodestone which draws it to the earth or pushes it away at will. This satire reads not unlike a learned treatise.

> "But the greatest curiosity," writes Gulliver, "upon which the fate of the island depends, is a lodestone of a prodigious size, in

shape resembling a weaver's shuttle. . . . By means of this lodestone the island is made to rise and fall, and move from one place to another. For, with respect to that part of the earth over which the monarch presides, the stone is endued at one of its sides with an attractive power, and at the other with a repulsive. Upon placing the magnet erect, with its attracting end toward the earth, the island descends; but, when the repelling extremity points downward the islands mounts directly upward. When the position of the stone is oblique the motion of the island is so too. For in this magnet the forces always act in lines parallel to its direction.

"By this oblique motion the island is conveyed to different parts of the monarch's dominions. . . . When the stone is put parallel to the plane of the horizon, the island stands still; for, in that case, the extremities of it, being at equal distance from the earth, act with equal force, the one in drawing downward, the other in pushing upward, and consequently no motion can ensue."

While the myth of the suspended image seems to have had little effect on the course of human progress, the magic mountains persisted in dislodging reason. When Columbus on his voyage discovered the variation of the compass from the

true north or pole star, it did not disturb him because his belief was that it was not the star which attracted the needle. He had the same idea as Roger Bacon that any compass needle would point east or west, north or south, depending upon how it was rubbed on the lodestone, and that the usual north position was merely a resultant of all the attractions.

Having some regard for his life, however, Columbus didn't expound this deep thought to his terrified sailors but invented the much more (to them) believable tale that the pole star had shifted its position a bit and would be O.K. to-morrow. This seemed quite reasonable and satisfied all hands. The next day the compass pointed true north because the ship was then approaching a line of no variation, as Columbus well knew, apparently from observing the gradually decreasing variation of the previous days. This agonic line became the famous dividing line of Eastern and Western trade territories allotted between Spain and Portugal by Pope Alexander VI, thus giving rise to Magellan's voyage around the world.

Among sailors generally, however, the variation, so noticeable now that they used the compass continually and over a wide area whereas heretofore it had been used only in cloudy

weather when the pole star was hidden from sight, gave impetus to the myth of the magic mountains. Maps began to show their location north of Greenland, and from time to time they were shifted about to various positions south of the real pole. Men became interested in them and wondered what they looked like. Venturesome souls began journeys of exploration to the far North which have continued through the centuries. The vision of the whole earth spread out before scientists and they began to attack cosmic problems with renewed vigor. Purely philosophical discussion about nothing in particular was now centered on the earth.

Peter de Maricourt (Peregrinus), who won his spurs in the Crusades, had long before concluded that "from the poles of the world the poles of the magnet received their virtue." He really meant the poles of the universe, not any earth poles; but, in his work, he built a globular magnet of lodestone and found that it had poles. He dreamed that it could be mounted somehow on the fixed, immovable earth so that as the heavens rolled around, his little globe would be rotated after them by some magnetic action and form a neat timepiece.

He never tried it, of course, but it inspired him to devise (on paper) a perpetual motion

machine on somewhat similar principles, moved by the virtue put into the lodestone by the Creator, whereby Peregrinus might be the instrument of Almighty God chosen to free men forever from distasteful labor. While he was dreaming, he apparently had a vision of what would certainly happen to him if he made this idea public, so fear of the stake sort of congealed his mixed religious and scientific fervor. This idea, however, expressed in a confidential letter written from the trenches in front of Lucera in 1269, is without question the first thought of changing electrical energy into mechanical energy, the first dream of the electric motor, a forerunner of the modern slogan, "Do it electrically."

Peregrinus went back to his knitting, but from his discoveries we first got the mariner's compass, where the scale moves with the needle and the azimuth compass, whereby, as he says, "you may direct your course toward cities and islands and all other parts of the world, either on land or at sea, provided you are acquainted with the longitudes and latitudes of those places." He it was who first mounted the compass needle on a pivot in place of floating it in a bowl or basin, and this, of itself, was a tremendous forward step.

His work, unfortunately for the world, was more or less hidden for three hundred years but that the result was finally appreciated, our old friend Norman testifies to in the poem of which a verse is quoted in the previous chapter. This time it is the compass needle speaking:

> "I guide the Pilot's course,
> His helping hand I am.
> The Mariner delights in me,
> So doth the Marchant man."

Mother's little helper, as we would phrase it now.

Gilbert gained much from the work of Peregrinus, particularly seeing in the globular magnet a miniature of our earth and on this thought he builded, discarding forever the magic mountains as separate entities but looking at the earth itself as a mountainous magnet with magnetic poles and a field of magnetic force around it, thus giving for the first time the true explanation of the action of the compass as well as laying the sure foundation of philosophy which through many intricacies led Newton to his matchless discoveries of the laws of gravitation and of motion.

In 1831 the north magnetic pole of the earth was located just inside the Arctic Circle by Sir J. C. Ross.

To that same lovable John Baptista Porta who was reviled by Gilbert we owe the first mention of direct communication through space. He was no doubt a genius and a great celebrity in his day, an intimate friend and confidant of the majestic Venetian friar Pietro Sarpi, better known as Fra Paolo, of whom Macaulay says, "What he did, he did better than anybody." This would be faint praise, indeed, applied to some of us.

Porta seemed always ready to try anything once, especially if some one else suggested it. He seldom tried out his own ideas, although he made a steam engine, the first since that made by Hero, 120 years before Christ. He believed with Alexander of Aphrodiseus that lodestone actually hungers for iron. When Jerome Cardan, one of Gilbert's "chattering barbers," whose life is almost fabulous in its quick rise from a starved and shunned gambler, scholar, and physician to the greatest living authority of his age in his profession, suggested that a magnet is best preserved in iron filings because "iron is the magnet's food," Porta took him literally, buried a magnet with a lot of filings and from time to time dug it up again to see how much it had eaten. The fact that nothing happened didn't bother him at all. He just passed on to

something else, no doubt believing in the truth of the title to Cardan's book, which, translated freely, professes to be a treatise "on all things with difficulty comprehended" and included a lot of things not comprehended at all, especially by the author.

In 1589, less than a year after the defeat of the Spanish Armada, Porta took advantage of his admission to the Lyncei Academy as a protection, according to Benjamin, against any accusation of practicing the "black art" and issued his twenty-volume treatise which was reprinted in London in 1658 under the title of "Natural Magic."

In the last volume he shows that he, like Peregrinus and some others, was aware of the "sphere of virtue" surrounding the lodestone. He compares the effect, in a way, with the light of a candle thrown out in all directions. Out of his conjectures as to the extent of that "sphere" he derives the notion that it has no end and that if one secured two sympathetic magnets and moved one, the other, wherever it might be, would move to exactly the same position. This, of course, is a sort of survival of Bacon's idea that the magnet didn't point anywhere in particular of itself.

Then Porta has one of those majestic thoughts,

so rare in this mercurial soul, and this is what he says:

> *"To a friend that is at a far distance from us, fast shut up in prison, we may relate our minds; which I do not doubt may be done by two Mariner's compasses having the alphabet writ about them."*

Here is the first thought of communication at a distance without an intervening medium and in it we have for only the third time in many thousand years any idea of turning magnetism or electricity to the material service of mankind. And even stranger than the materialism of the thought is its sequence from candle rays to magnetism to communication, when we remember that it was proof of identity between light waves and electromagnetic waves that led to radio three hundred years later.

Of course this speculation when it became known caused great discussion. It was affirmed, denied, and improved upon in conversation and on paper, but it fell to that same doubting Thomas Browne first to try it. No matter what he may have thought of the garlic myth when he set out for its destruction, he fell on Porta's thought and was caught, hook, line and sinker. At much expense he rigged up two elaborate

compasses with alphabets "writ about them" and feeling confident that if they would work at a distance, they should work near each other (although this had been strenuously denied!) he tried them in his home, but, no matter how he moved the one, the other didn't budge a bit from its north pointing, standing as he said, "like the Pillars of Hercules."

Many philosophers discussed this idea, including Daniel Schwenter who suggested the use of a bell that the needle was to hit when, as and if it turned; DeBoodt, the German mineralogist; Galileo in a delightful dialogue with Sagredo taking part. Strada, the Jesuit professor of rhetoric at Rome, to whom the idea is almost universally but just as erroneously accredited, makes much of it in a literary effort (1617) from which Addison borrows the thought to use in the "Spectator" and the "Guardian."

Even Browne's failure didn't altogether kill the germ, and frequent were the predictions that some day this dream would come true, the most remarkable one being a letter from Beal to Robert Boyle in 1670, wherein he is certain that "we have a perception at great distance," whatever the means or manner may be, "whether aërial, more refinedly ethereal, intelligent or astral," whatever that means, and in this he is

more confirmed "when we see how quickly the sun beams do pass to the borders of this vertex."

The thought of "action at a distance" was born!

This thought led to Radio.

CHAPTER III

SIDESHOW AND CIRCUS

"Science moves, but slowly, slowly, creeping on from point to point."

—Tennyson, "Locksley Hall."

UP to the end of the fifteenth century, as perhaps the reader has surmised, the lodestone and the property of magnetism created by it were both the subject of many superstitions and wild beliefs which had persisted for centuries. After this time many more notions were added to the ancient ones until the combination of difficulties, troubles, and tribulations which one could get into or get out of, by some magnetic method surpasses belief.

The lodestone, says an early writer, is the special friend of burglars for, if "burned in the corners of a house, it causes the inmates to believe that the building is falling; and so terrified are they with fancies that they fly out, leaving everything behind them and, by this artifice, thieves seize on goods." Chicago and New York papers please copy!

It takes away fears and jealousies; renders a person gracious, persuasive, and elegant in conversation; forms a test of connubial fidelity; is a means of marital reconciliation. Carried on the person a magnet will cure gout and cramp, draw poison from wounds, prevent baldness, cure headache, lessen pain, and facilitate parturition. It will draw gold from wells, "if pickled in the salt of a sucking fish," and mixed with nettle juice and serpent fat will make a man mad and drive him from his kindred, his habitation and his country.

As a guard against these evils or these blessings, one no longer had the comforting belief that garlic destroys magnetism or that a diamond affects the lodestone. One was, in fact, helpless in the hands of the physician, a condition reflected to-day by the attitude of the public mind toward anyone who signs himself "M.D."

Bombast of Hohenheim, sometimes called Paracelsus, but really named Aurelius Philippus (?) Theophrastus Bombast ab Hohenheim, was born in Switzerland in 1493. He was one of the first fakers to take advantage of all these ideas and with him began a line of cure-all practitioners who even in recent times have not passed from us. Bombast believed everyone

literally to be a magnet. "A magnet," says he, "may be prepared from iron that will attract iron and a magnet may be prepared out of some vital substance that will attract vitality." This being so, he sees in the magnet a cure for all ills, affirming that it has power over all disease. We would like to think that our English word "bombast" was derived from his name and nature, but lexicographers seem to be against us. Probably the reverse is true.

These beliefs were largely current when the Puritans touched our shores. Most of them had been in vogue when Columbus made his historic voyage. Bombast lived between these two events but rather closer to the time of Columbus. His career ended in terrible poverty and illness and he died in 1541.

He has frequently been called a martyr to science and, indeed, his life was not altogether spent in playing on the incredulity of the populace. The world owes to him the therapeutic value of laudanum and the compounds of mercury. He was among the first to storm the citadel of medicine and proclaim the doctrine of freedom of thought, breaking through all precedent by lecturing to his students at Basle in their native German instead of Latin and in their presence burning the venerated books of

the alchemists while announcing to all and sundry that his beard, his hat and his shoes knew more of medicine than all the ancient physicians put together. He was a great chemist and perhaps a great physician for his times.

In physical science, however, he was a total loss unless we look beyond his actions to his preaching of the value of the experimental basis of belief rather than to take things altogether on faith. He did proclaim this idea widely a century before Bacon, but like many of us nearer home, he practiced the exact opposite to his preaching and played upon the faith and superstitions of his hearers with the consummate skill of a modern side show barker.

Long before Bombast's preachings, other philosophers had occasionally strayed from the ancient belief that their first duty was to evolve a plausible theory regardless of possible facts. Many had gone so far as to admit mystification over various simple phenomena which didn't seem to work out in accordance with their beliefs but they had little to work with. The fundamentals were that a lodestone does attract iron, and substances similar to amber when rubbed, attract all manner of chaff. The one effect was magnetism, and the other was electricity.

And with William Gilbert the division of

scientific effort begins. Electricity became the sideshow, attracting to its tent no less genuine talent but the results were so spectacular as to amaze the experimenter almost as much as his audience and each experiment turned into a thrilling stunt. There were the fakers like Paracelsus, ancestors of the magnetic belt and electric combs of the mauve decade; natural geniuses like Von Guericke, the burgomaster of Magdeburg, stumbling to fame along a rainbow path; and to add a merry touch came King Charles II and his court making science fashionable. Then followed Gray and the magnificent Dufay.

Into the main tent left vacant by Gilbert's death, stepped Francis Bacon, Edward Wright, the sea mathematician, Gerhard Mercator, the map maker, William Barlowe, the navigator, Galileo, Descartes, Isaac Newton, Edmund Halley, the astronomer, and a host of others bent on solving the problems of earth and heavens and finding in magnetism an inspiration and a meeting place. They continued speculation based on what they saw while around them others took to experimental work. With the changing conditions and changing thought, speculations became more fruitful of lasting results. Picture what those results were.

Galileo, the Italian, gave us the astronomical

telescope and opened wide the heavens the while he brought himself before the Holy Inquisition in 1616 and again in 1633 where he was forced to deny his beliefs and discoveries on pain of being burned alive as Friar Giordana Bruno had been in 1600 for believing in the Copernican theory that the earth moves round the sun. But the red haired old man as he rose from his knees is said to have stamped his foot and whispered to a friend, "Nevertheless it does move!"

Such was the mighty will of him who multiplied our eyesight and soon lost his own in total blindness. We pause a moment to read the lament of Father Castelli, his friend and pupil: "The noblest eye is darkened which nature ever made; an eye so privileged and gifted with such rare qualities that it may with truth be said to have seen more than the eyes of all who are gone, and to have opened the eyes of all who are to come." We like to remember that Milton mentions having called on Galileo. Ships passing in the night!

There was René Descartes, the Frenchman, who perfected the Cartesian or descriptive geometry, gave us a theory of light and one of the solar system, told how the planets came to be, and the relation between tides and the moon, results to associate with Kepler's laws and tables.

His glorious aim was to create from the beginning a complete system of human knowledge, a task which Francis Bacon had undertaken before him and shied away from, leaving only a skeleton framework. "Give me matter and motion," cried Descartes, "and I will construct the universe." We shall hear of him again.

Then there was Isaac Newton, the Englishman, born the year Galileo died, who in his famous orchard evolved the law of gravitation and the laws of motion and then lost his mental bearing when his pet dog "Diamond" destroyed his life work in chemistry. Bacon, Galileo, Descartes, Newton! What a grand all star performance was given to the world in the realm of speculation!

Meanwhile in the tents along the "Midway" where quack, faker, and strong man each had his little following, there was a surge of interest toward one Otto Von Guericke, who had already attained a reputation. He had studied law at Leipsic and mathematics at Leyden. In 1650 he invented the air pump and later the air balance and had predicted the weather by weighing air, just as now the barometer does it for us automatically.

He had amazed Emperor Ferdinand and all the princes by putting face to face together two

empty hemispheres of copper, forming a globe about a foot in diameter, the halves not fastened and yet thirty horses could not pull them apart while at his magic touch they fell apart themselves. This is the famous Magdeburg experiment which for the first time showed the enormous pressure of the atmosphere. Von Guericke had merely exhausted the space within the globe by means of his air pump.

Then the Burgomaster turned his attention from air experiments to the electrics and by devious reasonings he emerges in 1672 with a globe of sulphur mounted on an axle and turned with a crank. The directions are "to stroke the globe with the dry palm, so that it may be rubbed or submitted to friction thus twice or thrice. Then it will attract the fragments, and when turned on its axis will take them along with itself." He had merely a convenient means of continually rubbing sulphur, one of Gilbert's electrics, in order to electrify it and keep it continually charged, but he continues: "In this manner is placed before the eye the terrestrial globe, as it were, which by attracting all animals and other things which are on its surface, sustains them and takes them around with itself in its diurnal motion in twenty-four hours." So he goes on for a while building up

a theory of the whole universe as most everyone did in those days when he made even one successful experiment.

Von Guericke noticed that tiny particles attracted by the globe would after a while be repelled, just as bits of paper attracted by your rubbed up fountain pen will themselves be charged in time and then be repelled by the charge on the pen. Like charges, as we now know, repel each other. But Von Guericke thought he had discovered an "explosive vertue." He takes the globe out of its bearings and chases around the room driving a repelled feather before him and he notices (How observant those old men were!) that "if one places a lighted candle upon the table and drives the feather at a distance of about a hand-breadth from the candle up to the globe, the feather suddenly recedes and flies to the globe as a sort of guard."

The charge on the feather was dissipated by the electron stream from the hot candle, but it was to be nearly 300 years before anyone knew about this and then we would have vacuum tubes in a radio set based on this little incident casually noticed by the learned burgomaster chasing a feather around a room in Magdeburg with a huge globe of sulphur in his arms!

Von Guericke finally concludes the globe is

animate. "When it does not want to attract," says he, "it does not attract." A good many believed the early radio sets worked on the same principle!

However, Von Guericke's importance lies in the fact that this is the first electric machine. Hauksbee substituted glass for sulphur in 1709 and soon after, instead of a globe, a cylinder and then a circular glass plate was used. Later instead of rubbing with the hand, friction was given by a cushion rubbing on the plate.

Many other improvements followed but in them all is the thought of frictional electricity accumulated on the thing rubbed. These machines will be with us and important almost up to the present age. Darwin once devised one but the latest and best came from the work of Holtz, Voss, Toepler, Kelvin, and Wimshurst.

The good burgomaster was to do more. He was to find that a thread hanging down from any support to a position near the globe would recede and "not allow the finger to meet it." So then he fastens the thread to a pointed stick from which it hangs vertically almost touching some object at the lower end. When the charged globe is brought close to the point of the stick the lower end of the thread is found to move to the adjacent body. He has passed an

electric charge down through the thread, the first evidence of a conductor of electricity. But Von Guericke sees merely that the excited globe can act through a thread "an ell or more long."

Von Guericke was to see one other amazing thing. He says to rub the globe with the dry palm, then if "you take the globe with you into a dark room and rub it, especially at night, light will result, as when sugar is beaten." . . . "There is likewise a virtue of sound in this globe," says he, "for when it is carried in the hand or is held in a warm hand and thus brought to the ear, roarings and crashings are heard on it." He has seen the discharge of tiny sparks and heard their crackle, just as you will some dry morning in the winter as you comb your hair or stroke the cat. He has seen the lightning in miniature and heard the tiny thunder claps but doesn't know it.

In England Oliver Cromwell was dead, Richard Cromwell had fallen and Charles II was on the throne. The Royal Philosophical Society had been formed and that careless, dissipated and dissolute sovereign not only beamed upon it with his kingly smile, but forsook for the moment his more evil ways to take part in the lively pursuit of science, discussing with great gusto and real interest, the ponderation of the

air, variations of the compass, and the amazing action of the barometer in telling what the weather was to be.

Fashion followed the king, men and women alike dabbling in the latest fad. The Duchess of Newcastle herself was invited to visit the new society "after much debate pro and con, it seems many being against it" and "after they had shown her many experiments," records *Pepys' Diary* (May 30, 1667), "and she cried still she was full of admiration, she departed."

In this crowd was Sir Christopher Wren, architect of St. Paul's cathedral and of a portion of Westminster Abbey, toiling on his work for $20 a week which he frequently didn't get. He devised the first recording weather gauge, the registering thermometer, a rain gauge, and many other meteorological instruments.

Governor John Winthrop of Massachusetts Bay was writing from the new world to Mr. Robert Boyle asking whether lightning could kill fish as the Indians affirmed and William Penn was reporting to the Society the immense resources of Pennsylvania. Robert Hooke was trying to build "artificial muscles" for a flying machine and gradually drifted toward the idea of using "horizontal vanes a little aslope to the wind." Roemer was observing the moons of

Jupiter through Galileo's telescope, resulting in a determination of the speed of light. Truly one did not know which ring or platform of the circus to keep his eyes on nor which tent of the sideshow to enter.

Thus the seventeenth century went by and a few years into the eighteenth. Francis Hauksbee, who had replaced the sulphur ball with his glass globe machine, was dripping sparks from his finger tips, while across the ocean Cotton Mather soon to join the Royal Society would have gloried, no doubt, in squashing him between two stones, if he had lived in Salem a few years previously. He brings an exhausted bottle near his electric machine and the bottle glows with light just as you can sometimes hold an evacuated bulb under a dry moving belt in a machine shop on a winter's day and see a ghostly glow. The idea of induction is thus born, an electric charge on one thing causing or "inducing" an effect on something else near by. Action at a distance again. Dr. Wall had seen in the electric spark and crackle a resemblance to lightning which Franklin was to prove is so.

The time of royal interest had gone forever and the wheel of life had spun again. George II was King of England. The place was the old Charterhouse School, "a masterpiece of

English charity" and the chief actor is one of the poor brethren, Stephen Gray. In 1720 Gray had appeared at the Royal Society and told a little of what he had done, then disappeared for years and misfortune had continued with him because all his communications are from the charity school.

Gray used a glass tube for his electric and thinking to keep the dust out he closed it with corks but much to his surprise the corks attracted a feather as well as did the rubbed glass. Unlike Von Guericke, Gray fell to speculating on this and hit upon the idea that the electric virtue would pass through bodies in contact, so he put longer and longer wooden rods into the cork with an ivory ball "which he had by him" on the end, and it worked well, attracting objects brought near to it.

He tried wire, both brass and iron, but being so thin they caused the ball to bob up and down and he reverts to thread. What a pity! For the ball he substituted a fire shovel, poker, coins, a tea kettle both empty and full. They all worked. Then he put into the cork his 14 foot fishing rod, and other rods until he had 32 feet of rod, and the ball on the end became electrified just as well as before.

In 1729 on visiting a Mr. Granville Wheler,

member of the Royal Society, and showing his experiment, Gray's host became even more enthusiastic than the poor brother himself and with the help of servants a pack thread line was erected 147 feet long, supported by silk, and the ball worked. Some of the silk threads gave way so iron wire supports were substituted and although the glass tube was rubbed briskly the ball showed no effect.

This led to Gray's discovery that the material of the supports was important, some material causing much loss of the electric virtue. So going back to silk, Gray and Wheler erected a successful line 650 feet long and for a while it worked as well as the others but in the late afternoon it failed and Gray remarks that he could not tell whether the failure was "caused by the dew falling" or by his getting so hot running back and forth from one end of the line to the other, "but," he says, "I rather impute it to the latter."

Back in the charity house Gray suspended boys upside down on ropes and bringing the charged tube to their feet, he caused their faces to attract chaff, proving that the body was conductive. To Gray goes all the glory of being the first to see a difference between what we now call conductors and insulators. It remained for

a Frenchman, Charles François Dufay, to carry Gray's work to a usable conclusion.

Gray had stated that the color of substances affected their attraction. Dufay took this for granted at first and it seemed to be true but soon he began to doubt. He found the petals of a red geranium just as susceptible as the green leaf, while Gray had said that anything red was attracted very much more strongly than anything of the same kind which was green. For final settlement of this question, Dufay hung up a number of strips of white cloth and breaking the sunlight into its spectrum with a glass prism, he caused the different colors to fall on the various strips while he was attracting them. But in no case was any effect of color on the attraction noticed. Both he and Gray had been misled by the conductive effects of the various dyes used for coloring, just as in the year of our Lord 1923 many radio fans got the notion that green covered wire couldn't be used for radio and some experts advocated white or red, and others brown when, in fact, there is no difference between them but only in the conductivities of the dressings and dyes used by some manufacturers.

Dufay then proceeded to upset the fundamental idea of electrics and non-electrics by

showing that anything can be electrified although the effect on metals seemed so slight that he hardly believed he had noticed it until on happening to support some metal on glass rods, he found he could not only electrify it but could do so much better than with anything else. Right then it dawned on him that electrification depends not on the nature of the substance, but on so supporting it that the virtue does not leak off. He substituted solid insulators of wax or glass for Gray's silk supports and on them electrified stones and oranges, books and red hot coals.

Somewhat disbelieving Gray's conclusions, after having proved him wrong on the color question, Dufay goes back to line transmission and finally finds that metal wires or wet objects, those things difficult to electrify, conduct the virtue best of all while those easiest to charge are best as supports or insulators. On the former, of course, the charge passes right off while on the latter, being non-conductors, the charge remains stationary and can be detected. Dufay built a line a quarter of a mile long of wet thread held up on glass tubes and found it capital to convey the virtue from one end to the other. Thus he gave us the electric wire, the first real big step towards modern electricity.

How many ever have thought of the stupendous value of this simple discovery which was so many years in the making and approached so closely by so many men who couldn't recognize it? Without first having the "wire" how could we ever have had the "wireless"? That is a profound question!

And now Dufay goes a step further in his destruction of time-worn theory. He finds that a bit of gold leaf repelled by the rubbed glass is attracted by rubbed amber or copal gum and when repelled by the latter substances, is attracted by the glass. He tries it over and over again and then announces that there are two kinds of electricity, vitreous and resinous. We shall see how well this theory held up.

Dufay and Gray corresponded cordially for the rest of their lives and both received many honors and compliments. The one died within the old gray walls of Charter House on February 15, 1736, dreaming at the last of the planets controlled by electrical influences. The other passed away in France three years later leaving as his monument the Royal Botanical Gardens in Paris, which he had organized while carrying on his electrical work. In their great discoveries there is glory enough for both. They carried us a long ways toward a knowledge of electrical phenomena.

CHAPTER IV

A REAL KICK IN A BOTTLE

"The fire and cracks of sulphurous roaring."
—SHAKESPEARE, *Tempest* I:2

THE discoveries of Gray in England and of Dufay in France gave a new impetus to the study of electric effluvia as it was now called. Even more spectacular effects could be obtained than in the days of Von Guericke for now the source of the current, the electric machine, could be concealed and wires could be run to wherever an experiment was to be performed. With the improvements in Von Guericke's machine made by Hauksbee and others, it was possible to secure sparks of a startling nature. It was a long advance from the tiny effect that Gilbert knew when he rubbed diamonds and amber, but still the machine had to be operated just as long as the effects were desired. This was the situation in 1745, six years after Dufay's death.

Even that date was a long time ago as men's

lives go. Napoleon Bonaparte, whose name fills more pages of this world's history than that of any other human being, had not yet been born and would not be for nearly a quarter of a century. Benjamin Franklin was 39 years old and had been entertaining and instructing the inhabitants of Philadelphia for thirteen years with "Poor Richard's Almanac." He had been to England learning something more of the printer's trade, of human nature and women's whims and now, somewhat at ease financially, was frugally performing that multitude of scientific experiments which later was to make him world famous. Fulton was not yet born and "Fulton's Folly," the steamer *Clermont,* was sixty-two years in the future.

In 1745 there was no United States. Men lived who had talked with some of the *Mayflower's* passengers. Along the coast were the few scattered settlements all loyal to the crown and elsewhere was the Indian gradually learning the merits of the white man's whisky. France and England had equal interests over here and the war between them was on. George Washington as a youth of thirteen was learning surveying and ten years hence he would be with Braddock at his defeat and death near the beginning of the French and Indian War.

On the throne of England still sat George II, grandfather of his ill-fated successor and namesake, George III, who was destined to lose the brightest jewel of the British crown and thus become immortal. The young pretender, Charles Edward, had landed in Scotland and the second Jacobite rebellion was in full blast.

In Russia, Peter the Great had died only twenty years before, leaving as his monument the village of St. Petersburg, now Petrograd or Leningrad, built on the swamps of the river Neva even as in our own times the newer city of Miami rises from the filled-in shallows of the Florida shore. Philip V was at death's door, after founding the Bourbon line of kings in Spain. Frederick the Great was defeating the Austrians and Saxons in the first of that long series of fights ending before his death in 1786 in the League of German Princes, the foundation of the mighty German Empire which is now a memory. In France Fleury was dead, and the country was enjoying government of mistresses and ministers.

In Western Europe was a little country called the Netherlands, sometimes known as Holland. The Spaniards under Philip II had besieged the city of Leyden one hundred and seventy years before, but without success, and in reward for

the courageous defense made by the starving inhabitants, a great university was founded in the town by William of Orange in 1575. This became one of the most famous seats of learning in Europe and in 1745 Pieter van Musschenbroek as Professor of Philosophy was attracting crowds from all over the civilized world.

Musschenbroek was born in Leyden in 1692 and educated there. He practiced as a doctor for four years and then for some reason not now recorded, he quit doctoring and in 1719 was appointed Professor of Mathematics and Philosophy at Duisberg in Germany. He went from Duisberg to Utrecht. Denmark tried to get him to Copenhagen. The English king invited him to Göttingen. Spain offered him an enormous salary. The Empress of Russia and the King of Prussia both sought him in vain. In truth rulers vied with one another for the services of this popular lecturer but he preferred to go back to his native land and town, and there he spent the remainder of his life in the study of this rubbing or frictional electricity.

Philosophers everywhere were still playing with frictional electricity. They still had no object in view. Tallow candles and open fires gave all the illumination that one had. Streets were dark except for an occasional dull gleam from

an inclosed candle above a house door in the larger settlements, and in the cities abroad lamp or torch bearers guided the wayfarer to his home. The horse was the sole means of rapid transit on land.

There was no available source of power other than man, or an animal treadmill, or an occasional waterfall with its huge mill wheel. Water transportation over long distances was possible only in sail boats. Over short distances some of the wealthy had barges rowed by slave gangs, sometimes in relays. Communication was by word of mouth or by letter sent through the kindness of some traveler and later by the infrequent post. Men broadcast their thoughts by the printed pamphlet and many a glorious row resulted because denial was useless. The record was in black and white.

In 1745 there was neither speed nor power, neither entertainment nor communication in the modern sense. There was no financial value attached to electricity. It meant nothing to anybody. No one knew what it might be good for.

In America Franklin was wondering if the electric effect was really that of a subtle fluid. He was proving that it was not created but only drawn out of bodies. In France, Abbé Nollet, who wasn't a priest but had put on the name and

dress of an abbé the better to have a standing at court, was entertaining the smart set at Versailles with sparks and crackles, something as in the days of Charles II in England the savants of the newly formed Royal Society amused society. Electricity was still an intellectual football and a parlor trick.

In Holland Musschenbroek conceived the idea of confining or bottling the effluvia from an electric machine for use at any time. Whether he worked alone or with his pupil Cunaeus we don't know. Some say that Cunaeus merely repeated experiments that Musschenbroek related to him and later to Réaumur in a letter which Nollet published. Others give credit to Bishop Kleist of Pomerania. In any case the idea was that if the water in a glass bottle were electrified and the bottle closed by a stopper, it would remain charged for some time because the bottle was of insulating material.

In spite of Dufay's discoveries, Gordon had about this time announced that blue silk threads were good insulators and so blue silk was in fashion. Musschenbroek used blue silk threads to support a gun barrel. One end of the gun barrel was connected to the friction machine and a brass wire dropped from the other end of the gun barrel into a glass jar partly filled with

water. In the most dramatic form of the story, Musschenbroek turned the crank while Cunaeus held the jar in his right hand and with his left hand attempted to draw sparks from the gun barrel.

Here another one of those strange pranks which fate plays with us poor mortals comes into the picture. There was no reason for the belief that water could be charged any differently than anything else and, of course, it can't. Normally nothing would have happened if the jar had been placed on a stand or table in the usual way others had electrified substances but being grasped in the hand, the latter formed a conductive coating for the outside of the glass jar. The water inside was the other conductor. The glass jar was a dielectric or insulator in between two conductive masses. Unconsciously a condenser was formed although nobody had ever heard of a condenser. By accident and in entire ignorance Musschenbroek had arranged things in the only possible way in which anyone would ever have gotten any results whatever.

After a suitable time, of course, the condenser charged up and when Cunaeus poked his finger at the gun barrel, he must have thought someone pulled the trigger. A terrific spark resulted, the entire charge passing through Cu-

naeus as if lightning had struck him. It knocked him down and for two days he was incapacitated. Musschenbroek records the terrific effects in that letter published by Nollet. Speaking of the experience he had himself in trying the experiment he says, "The vessel . . . was not broken . . . but the arm and body were affected in a manner more terrible than I can express. In a word, I believed that I was done for."

Nollet, however, saw the spectacular in it, but having no desire to try it himself, he got together a crowd of nearly two hundred soldiers at Versailles and shot a good stiff charge through them all joining hands, with a somewhat similar pleasing result. They all jumped together, which showed the instantaneous travel of the effect, a new source of wonderment, a new discovery, the effect was instantaneous!

Musschenbroek's experiment was really the first step toward radio since the suggestion of Baptista Porta nearly two hundred years before. All through the history of wireless telephony and telegraphy the condenser has played the leading part. Without it wireless would be impossible. In the early investigations the condenser was all. There was no coil.

To-day the condensers in your receiving set

are the things the dials are fastened to. You adjust them to tune in. Sometimes there is one, sometimes two, and in many cases there are three, either worked with three separate dials or all fastened to one shaft operated by a single dial. All of these condensers are patterned after the Leyden jar. In your set, in place of Cunaeus's hand you have stationary metal plates; instead of the water inside the jar, there are rotating metal plates. To take the place of the glass in between, you have air, the best insulator there is for the purpose.

It took Musschenbroek, Nollet, and the rest of them a long while to figure out what had happened. When they placed a jar of water on the table, it couldn't be electrified for, of course, any charge would run off through the wire to the machine. The outside hand seemed to be essential. After some experimenting it was found that placing the jar on a metal plate connected to the machine worked just as well. Thus the idea of a complete electric circuit was born, a circuit from one terminal of the machine to the inside of the jar and from the outer plate to the other terminal.

Soon an outside tinfoil coating was substituted for the metal plate and before many years our own Benjamin Franklin substituted an in-

ner tinfoil coating for the water and knocked out of everyone's mind all the theories about water charging up. He went even further, and showed that the seat of the charge was entirely in the dielectric. It was the insulator that was put under electric strain, not the metal plates. This discovery is the fundamental fact on which Faraday and Maxwell during the next hundred years built the entire electrical theory that we know to-day. It is one of the major discoveries in science.

Leyden jars are still used in their original form and in the plate form, which quickly followed Franklin's early experiments, all commercial condensers are made. There has been no electrical change or advancement since Franklin coated both sides of the window panes of his house with thin metal in order to make condensers. If you should happen to meet Franklin, Musschenbroek, Cunaeus or any of their correspondents at a modern radio show, he no doubt would understand any of the modern condensers, fixed or variable, and could tell you most of what is known about condenser action. Probably Cunaeus would keep one hand behind his back if the batteries were connected. At least he wouldn't point!

Those early experimenters, as we have seen,

knew only frictional or static electricity which is always of high voltage or pressure like the lightning discharges to which it is compared. After Musschenbroek's discovery this electricity was very dangerous. Nollet, in particular, recognized this and staged many executions of birds, worms and various insects.

Low voltage current such as we use in radio set operation was unknown to anyone then. Strangely enough the man who was to be largely responsible for this low pressure current from batteries was born in the same year that the Leyden experiment took place. That man was an Italian and his name was Alessandro Volta, from which we get our term "volt" for the force or pressure of electricity. Whenever we speak of volts, we pay tribute to this great Italian pioneer, born in 1745 and fifty years later to become world famous.

These fifty years were important in the world's history. During this time Venice and Genoa were republics but in distress. In the Papal states, industry and prosperity declined. Spain, then of some importance among nations, was helping out in the War of the Austrian Succession. Portugal which for a century now had again been independent of Spain, suffered the terrible earthquake of Lisbon with the loss of

30,000 lives. Poland was being divided up between Austria, Prussia and Russia. Catherine of Russia was, as usual, fighting the Turks. England was fighting everybody, including the thirteen colonies in America. Surajah Dowlah in India had made the Black Hole of Calcutta known to history. Clive had retaken Calcutta, fought the French and defeated the Dutch.

The entire world was a battlefield except in Japan where an Empress sat on the Mikado's throne for seven years, and in Scotland Robert Burns was singing his immortal songs.

Those fifty years, too, were the last intellectual years of electricity for at least a century to follow. We have seen it the plaything of many brilliant minds, but not a single thought of utility has been evolved. It has been a mystery, an idea, a cause of brilliant discussion, experiment, and amusement. From the ancient amber through Gilbert, Guericke, Gray, Dufay, Musschenbroek, and Nollet no commercially useful device has come to light. Franklin, the Boston Yankee, sees a commercial possibility in the lightning rod but nothing more. It is the first golden fruit of the electric vine. In the nineteenth century other Americans—the lightning rod salesmen—plugged it to the limit.

In view of the widespread knowledge of elec-

tricity long before Franklin was born, and its inclusion in all types of literature, it is amazing how many modern writers credit Franklin with its discovery and some with its invention! Long's "History of American Literature" goes one step further in absurdity in referring the honor to Jonathan Edwards, as anticipating Franklin.

PART II

HOPE AND HISTORY

How the electrical science came into the service of mankind through the work of Franklin, Galvani, Volta, Oersted, Ampere, Faraday, Ohm, Maxwell, Joule, Fresnel, Bradley, Young, Hertz and many others.

CHAPTER V

THE CHURCH NEXT DOOR TO A BREWERY

"First let me talk with this philosopher
What is the cause of thunder."
—SHAKESPEARE, *King Lear* III:4

IT was in 1749, four years after the Leyden affair that there was suggested and two years later actually performed, the most majestic experiment ever conceived by the mind of man, but before relating the circumstances we must see the reason for it.

The ancients had believed that friction created this virtue of electricity, the name itself coming from the Greek word for amber, "electron" which relates to the golden sun-like color of the resinous stone. Benjamin Franklin had said to himself that if the creative theory is a correct one, then a person standing on a cake of wax or an insulating stool of glass, with one hand on the electrical machine which he rubbed with the other hand, would be electrified because he will be constantly taking electricity from the machine

and it can't pass away through the stool. So he had a friend try it and found that no sparks could be drawn from him.

Then he put two persons on two separate stools; A rubbed the cylinder and B touched it. Then Franklin could get sparks from either A or B. So he reasoned that each body has its normal amount of electricity. When A rubbed the cylinder he gave up some of his electricity to it and this passed to B. Then B had an overdose and A had less than normal. Franklin, of course, had normal. When he touched B the spark was a discharge of the excess from B through Franklin to the earth and then both he and B had normal amounts. Now, when Franklin touched A there was a spark from him to sub-normal A, passing part of Franklin's normal quantity into A.

If before being touched by Franklin A and B touch each other, the spark is greater than either of the sparks to Franklin. Thereafter if Franklin touches either A or B there is no spark at all, because the charges on A and B were equalized when they touched each other and both become normal. The one man alone on the stool couldn't become charged, Franklin reasoned, because what he gave up with one hand he received back with the other. These experi-

ments established Franklin's law of conservation of the electric charge.

Those which have too much electricity Franklin termed positively electrified and those with too little he termed negatively electrified. He believed there would always be a flow from a positively charged body to a negatively charged one, if they were joined. The essential of Franklin's theory is that there is only one kind of electricity while Dufay, you remember, decided there were two kinds, vitreous and resinous, and all of the scientific world had accepted that. In Franklin's theory "vitreous" was the positive and "resinous" was the negative. He was led to classify them in that way because, among other leading observations, he noticed that the flame of a candle is usually blown from a brass ball discharging "vitreous" toward one discharging "resinous" electricity, and so he thought that was the direction of flow of the electric fluid.

Abbé Nollet in France now led the European experimenters, and his belief was that electric phenomena were the movement of two "very subtle and inflammable" fluids in opposite directions but he supposed these two fluids to be present in all bodies under all circumstances. Part of this fluid escapes from the pores as an "effluent

stream" when the body is rubbed and this loss is taken care of by an "affluent stream" entering the body from outside. Light bodies, such as chaff, are caught in one or the other of these streams, says Nollet, and are either attracted or repelled. Nollet who about this time was stimulating plant growth by electricity in quite the modern manner, also believed in the identity of electricity with the "matter" of heat.

Franklin rather doubtfully believed much the same. "Common fire is in all bodies, more or less," he writes, "as well as electrical fire."

This was the situation which led to the arguments between Nollet and his followers and those who backed the then unknown American. Nollet's was a two-fluid theory. Franklin's was a single-fluid theory. Both believed in some sort of an effluvia which surrounded the electrified bodies.

In England William Watson had an idea somewhat like Franklin's and was trying to make his friends believe Franklin had sort of usurped his theory. In France, Nollet had run across a pamphlet of Franklin's and thought his enemies were spoofing him under a nom-de-plume, but when convinced there was a Franklin in America, he lashed out in defense of his own position. Franklin was the butt of all but a few

of Europe's thinkers in the electrical field when he conceived and is said to have performed the experiment referred to in the opening sentence of this chapter, thus establishing himself as the foremost scientist of his day.

Many men had remarked something of the resemblance between the electric spark and lightning but, just as for many, many years they had discussed the resemblance between the spark and common fire until Bose and Ludolff in 1744 directed the spark into an inflammable liquid and found it *was* fire, so far there had been only discussion. Lightning was believed by many scientists, and in 1737 Franklin was one of them, to be a burning vapor of sulphur because of the odor of the air after a flash. By some it was compared to some compound of nitrous and sulphurous vapors spontaneously exploded as if in a cannon, thunder being the report. Robert Boyle had casually spoken of the sulphurous smell when amber was rubbed but neither he nor anyone else had made any connection between this and the smell of air after lightning.

Franklin systematically compared the two phenomena. He saw in both the same jagged appearance. He noticed the tendency of lightning to strike pointed elevated structures such as steeples, masts of vessels, trees and towers.

He had already made much of "the wonderful effect of pointed bodies both in drawing off and throwing off the electrical fire" in his experiments. Remember Von Guericke's pointed stick and the sparks from Hauksbee's finger tips! He noticed that lightning ignites combustible matter, fuses metals, and kills animals. He also observed the crackle when a short spark passes and saw in the thunder merely a louder roar in proportion to the immensely longer spark of lightning.

All this Franklin set forth in a letter dated July, 1750, to the Royal Society in London suggesting that much harm done to property by lightning might be prevented by fixing upright pointed rods of iron, gilded to prevent rust, on the highest parts of lofty buildings, with a wire running from the foot of the rods down the outside of the building into the ground, so that the electrical fire might "be drawn silently out of a cloud before it came nigh enough to strike." This paper created much laughter and was ridiculed to such an extent that it was not printed and Franklin is said to have been much abashed, but he met the rebuff calmly.

In the letter Franklin had given an account of many of his newest experiments and had suggested as a means of determining whether or not

the clouds were electrified, that a protecting box be erected on the top of some high tower and a pointed iron rod run up through the box twenty or thirty feet into the air above the building to meet low hanging clouds. Then a man in the box on an insulated stand might be able to draw a spark from the rod.

Although the letter was not published by the Society, it was printed in 1751 as a pamphlet by Cave and was translated and published in France where it created much interest. The King ordered Franklin's experiments performed before him, which was done. As an aftermath the King's "Master of Philosophy" and D'Alibard, who had translated the pamphlet, got together to try the experiment with clouds.

In D'Alibard's garden a sharp-pointed rod was erected sticking some thirty or forty feet out of the ground and a servant set to watch for a thunderstorm. This happened to come some few days later when the servant was alone. Not waiting to go for D'Alibard, the servant touched the rod with a contrivance made for the purpose and saw a terrific flash with terrible flame and he smelled the sulphurous odor, which combination, reminding him of hell, scared him almost to death and his howls attracted mobs of the vil-

lagers, including a fearless priest who took great joy in repeating the effect a number of times while the storm raged "and every time the experiment lasted the space of a *pater* and an *ave,*" he wrote to his distant host.

When Franklin heard of this months later, he felt that the test was not conclusive. The rod was so low the fire might not have come from the clouds; so he determined to perform the experiment himself with a kite flying right up into the blackness of a thunderstorm. He well knew he might be killed. He had destroyed a huge turkey with the discharge from his powerful battery of Leyden jars and his own life had nearly been snuffed out by a shock from the same source. He knew the thunderbolt to be immensely greater. Although he reasoned that the charge would pass "silently down" a pathway provided for it, as he had silently discharged his battery without sparks, it was mere conjecture on his part. He knew nothing about the laws of conduction. He was staking his life on a theory. In 1753 Richmann at St. Petersburg in drawing fire from the clouds was killed.

With only his son aware of his purpose and accompanying him, Franklin went out into the open, flew his metal-pointed kite into the storm, holding it by a dry silk handkerchief fastened

to the thread or cord which soon became wet and hence a fairly good conductor. As he saw the loose fibers of the cord stand erect, without a tremor he reached out his knuckles to the key suspended on the end of the thread and watched the tiny sparks play between his hand and the key. He had drawn the electric fire silently from the stormy heavens!

He charged Leyden jars with it and performed all manner of experiments to show that it was the electric fluid with which he was familiar. He invented electric chimes to warn him of the presence of atmospheric electricity. His fame went round the world, his prestige was established and his theories were universally applauded. Franklin was made a Fellow of the Royal Society. Poor old Nollet had lost his fight.

At the time when all this happened, everyone believed in electricity being a sort of fluid, but Franklin pictured it as "particles extremely subtle, since it can permeate common matter, even the densest metals, with such ease and freedom as not to receive any perceptible resistance." Thus he explained that the Leyden jar is discharged only when a path is created between the coatings, the glass being a substance impermeable to the particles. But Franklin

was well aware that an electrified body would attract through a glass plate, so to be consistent he had to suppose that the nearest surface of the glass was directly affected and somehow able to exert a secondary effect on the opposite surface which attracted the body. This thought enabled him to reconcile the behavior of the jar with his theory by supposing that the excess of electricity on one metal coating acted through the glass to repel electricity on the other coating, which thereupon became deficient.

If you don't understand this, go on with the story anyhow.

To explain the attraction between bodies having an excess and those with a deficiency of electricity, that is, between oppositely charged bodies, Franklin assumed that although the "particles of electrical matter do repel each other, they are strongly attracted by all other matter." Two bodies with excess of electricity would, of course, repel each other because of the effect of the charges.

Some time later Franklin found that two deficient bodies (negatively charged) repel each other and he was sunk, but two of his European followers rushed into the breach, Franz Ulrich Theodor Aepinus and his co-worker Johann Karl Wilcke.

These two abandoned the idea of an electric body being surrounded with any "effluvia," but generalized that the charge or fluid is confined to the body itself and acts at a distance through the intervening space. Based on old Stephen Gray's experiment with two oaken cubes, one hollow and the other solid, but both showing exactly the same amount of electrical effect, they announced that the whole charge is on the surface of the body and that on conductors it is mobile.

They stated that all non-conductors are impermeable, even air, and to show this, they made a successful Leyden jar without the glass bottle, using just the coatings with air between them, the first air condenser.

To round out Franklin's theory and explain the repulsion between two resinously charged bodies (deficient in fluid) Aepinus made the amazing supposition that particles of ordinary matter repel each other and although this startled his contemporaries, Aepinus made them accept it and like it. With the distinction that we say unlike charges attract and like charges repel each other, the non-mathematical student to-day accepts pretty much the combined generalizations of Franklin and Aepinus.

Following this ingenious worker, a friend of

Dr. Franklin's named Joseph Priestley, ever honored as the great clergyman who gave birth to the science of chemistry by his discovery of oxygen in 1774, somewhat hesitatingly announced that the forces of attraction and repulsion between two charges vary inversely as the square of the distance between them. Although to the general reader there is no connection whatever, this is a mathematical result which necessarily follows (1) Franklin's communication to Priestley that a cork ball within an electrified metal cup is not affected by the charge on the cup and (2) Priestley's own showing in 1766 that there is no charge within an electrified hollow body and no force in the interior. Cavendish about 1771 made the same discovery but it was not published until 1879 by Maxwell. Coulomb, however, verified this law experimentally with the torsion balance in 1785 and he is generally credited with its origin. His name is commemorated in the unit of electrical quantity—the coulomb.

Now we have two laws of electricity, Franklin's law of conservation and Priestley's law of attraction. We have at last the beginnings of an exact science brought about by a brewery being next door to a church, for it is this fact as Priestley himself says in his autobiography that

turned Priestley's attention to experimental science. He was the pastor of the church and was much attracted by the abundance of gas, now known as carbon dioxide, escaping from the vats of fermenting grain.

He experimented with the gas and in the course of his experiments he secured some red oxide of mercury which he heated by means of a "burning glass," similar to what we now use as a reading glass. After a time he found that a gas was given off and the pure metal was left. He collected the released gas, which was oxygen, and noted its properties, the first time this element had ever been isolated. He met Franklin in London and was induced to write a history of electricity which, including his own experiments, brought him much attention.

Franklin and Priestley were strangely alike. Neither was a scientist but each turned to it for diversion. Both had been marked for the church. Both were tremendous examples of self education. Priestley taught himself Latin, Greek, Hebrew, Italian, French, German, Chaldean and Syraic and his proficiency was so great that Edinburgh gave him an honorary degree for this, just as later the same University honored Franklin with a degree.

Both wrote much of science and morals. They

were of similar temperament and character. Both fought the reactionary government of George III and both reluctantly gave up the English flag for that of the United States, Priestley barely escaping with his life to Northumberland, Pa., in 1795 after seeing his house burned and his library and instruments destroyed by a mob. His persecution, which he believed to be inspired by the government, was partly because of his dissenting religious and political views and partly because of his attitude toward the French revolution then in full blast. Priestley at one time was elected a citizen of the French Republic and was even appointed an honorary member of the National Convention although he was not a Frenchman.

We ought to notice here, in the light of later events, that in his "History" Priestley asks the question, "Is there any electric fluid *sui generis* at all, distinct from the ether?" That was a long way back but Maxwell answered the question for us almost exactly a century later.

We might notice, in passing, that this same Priestley gave the name "rubber" to that substance because he noticed that it would "rub out" pencil marks—which has nothing in particular to do with Radio.

CHAPTER VI

"WHAT PRICE FROGS' LEGS," SAID NAPOLEON

"From these and all long errors of the way,
In which our wandering predecessors went,
And, like the old Hebrews, many years did stray
In deserts but of small extent,—"
—Cowley, "Ode to the R. S."

PERHAPS never in the history of science has more fruitful work been done than at the close of the eighteenth century and the beginning of the nineteenth. Franklin's great discovery still held men's minds, though forty years had elapsed, when in Italy out of a clear, blue sky arose as bitter and unexpected a controversy as the dispute between Franklin and Nollet, and a controversy fraught with greatest importance.

Up to the time of Franklin, electricity could be generated only by friction, a little at a time. This could be used to charge a battery of Leyden jars by great exertion and then a considerable amount was available for a momentary experi-

ment. Franklin, as we have seen, discovered another source,—the clouds. Experimenters since have found a very considerable, though constantly varying, voltage at all times between the air at great heights and the earth, but no utilization of this potential has been seriously proposed although Mahlin Loomis, as we shall see, had a suggestion not entirely unconnected with this matter. But to return to our chronology.

In 1780, according to an apocryphal story which, whether true or not, will set forth the essential facts correctly, Madame Galvani was skinning some frogs preparatory to making soup, apparently for the delectation of her very distinguished husband, Aloysius Galvani, Professor of Anatomy at Bologna (founded 1200 A.D.). He had in his house a friction electric machine and it so happened that one of his assistants was working the machine while the skinning process was going on. Just as there was a passage of sparks the scalpel happened to touch a nerve in the leg of one of the frogs and to the surprise of everyone it kicked and struggled as though it were alive. Galvani was out, but on his return the circumstances of this accidental discovery were related to him and he found that he could repeat the experiment at will.

In true research fashion he tried the effect of touching the nerve with various materials and, in place of the electric machine, tried the discharge of a Leyden jar. Then he bethought himself of atmospheric electricity and wondered whether a lightning flash would have the same effect. So, preparing a number of frogs, he hung them by copper hooks on an iron balcony outside the house and waited patiently for a storm.

They not only responded to lightning flashes but also at times to any electrical condition of the air, as before a storm, for example. On one occasion as they swayed in the wind, the ends of the legs touched the iron and Galvani noticed the same convulsive effect, although there was no lightning and the air was clear. He pressed them firmly against the iron and each time saw the twitching and it suddenly came to him that this might be a clue to the secret of bodily motion. He visioned electricity as the vital force which causes muscular movement. He thought he had the world by the tail.

The anatomist was aroused and eagerly he proceeded to determine what was happening. He found that any two metals joined together, one touching a muscle and the other a nerve, would cause the contraction. So he declared the

muscle to be a kind of self-charged Leyden jar, the electric fluid passing from the inside of the muscle to the nerve and from the nerve around through the metallic conductors back to the outside of the muscle. To this fluid the names *galvanism* and *animal electricity* were given. We still refer to a galvanic battery and the distinguished Bavarian physicist Georg Simon Ohm later gave the name *galvanometers* to the early electrical measuring instruments.

Alessandro Volta, another Italian, Professor of Natural Philosophy at the University of Pavia (founded 825 A.D.) was one of those attracted by Galvani's discovery when it was published in 1791, just a few months after Franklin's death. Volta tried the experiments himself on frogs' legs. In fact, the market everywhere on frogs' legs showed a bullish tendency for nearly a hundred years. Laboratories were cluttered up with them. Galvani's experiment became a classic with the old school of physicists, some one of whom discovered that back in 1678 Swammerdam showed the Grand Duke of Tuscany that contraction in a frog's leg could be obtained by binding a nerve with silver wire and suspending the frog over a copper support in such a manner that both wire and nerve touched the copper. No one ever connected this experi-

ment with electricity, however, until after the time of Galvani.

Volta was not then as well known as the great Galvani but he took issue with the latter in 1792 and stated that the electric current did not originate in the leg but in the contact of the two dissimilar metals with moist surfaces. Galvani countered by showing that no metal was necessary. It was sufficient to simply touch the nerve to the exterior of the muscle.

Giovanni Fabroni of Florence also threw his hat into the ring, and denied the existence of any special virtue peculiar to animals. He showed that when two dissimilar metals are placed in water, one is oxidized if the two metals are joined and he surmised that some chemical action gave rise to the galvanic effects. We must note, too, that back in 1752 Johann Georg Sulzer had mentioned that if pieces of lead and silver be touched together and placed on the tongue, a taste is observed "similar to that of vitriol of iron." He decided that neither metal dissolves but "that the contact sets up a vibration in their particles, which, by affecting the nerves of the tongue, produces the taste in question," if you get what he means. He nearly made a discovery, but in science as in target practise, a miss is as good as a mile. In this connec-

tion, however, it is well to record that Helmholtz saw flashes of color when he passed current through his eyeball, Volta heard musical sounds when current went through his ear, and Humboldt found a sensation of smell with current passing from his palate to his nostril.

The phenomena of galvanism, aside from the kicking frog's legs, were pretty feeble and interest in the result waned considerably for years, but the scientific world divided into two camps on the explanation of it, those looking to animal origin and those thinking of the metals in moist contact, perhaps acting chemically. In any case it was agreed that there were no spectacular effects to show.

It so happened, too, that about this time Galvani got into trouble. It seems that he had been attached to the old régime overthrown by the army in the French Revolution. In 1789 the "powers that be" tried to force him to take the oath of allegiance to the new Cisalpine Republic and when he refused, they deposed him from rank at the University. He became melancholy, suffered domestic bereavement and died in poverty and disgrace before the end of the year. In 1879 a statue, long delayed, was unveiled to his memory in his native city. Men then knew that his theory was just as correct as Volta's but

that they were talking of two different phenomena.

Hardly more than a year after Galvani's death, Volta offset his opponent's production of current without metal by showing a very intense effect with only metal and without frogs' legs or other animal tissue. He devised a pile of couples, each couple a zinc disc and a copper disc contacting with each other face to face. Between each pair of couples was placed a disc of moistened pasteboard so that the copper of one couple and the zinc of the next touched the pasteboard on opposite sides. If a considerable number of such couples were made up into a pile, a decided shock was felt when the fingers touched both end discs at the same time.

This could be repeated times without number and the pile thus resembled a continually recharged Leyden jar.

Such an unfailing source of electricity was just what was needed for experiment. Volta soon found that the diminution of strength of the pile after a time was caused by the pasteboard discs drying out. So in 1800 he invented his famous "couronne de tasses" in which copper and zinc strips were joined at the ends and dipped into separate jars of slightly acidulated water. These were really batteries similar to

but much weaker than those now used for door-bell ringing.

As is so often true of an inventor, Volta quite apparently had no idea of the value or capabilities of his discoveries and quite as surely did not know the true reasons why they worked but nevertheless his fame became widespread.

Happening to be one of a delegation to go before Napoleon, the latter took a great fancy to Volta and his theories. Napoleon made him a Count and a Senator of Italy and gave him a gold medal. He demanded that Volta perform his experiments before the French Institute and ever afterwards if any Italian group called upon him and Volta was not in the front rank, Napoleon would abruptly ask, "Where is Volta? Can he be sick? Why did he not come?"

Some years afterwards he refused to permit Volta's retirement from the University, saying, "If his duties as Professor are too fatiguing, they must be lessened. Let him deliver but one lecture during the year, if desired, but the University of Pavia would receive its death blow the moment I allowed so illustrious a name to disappear from the list of members. Besides, a good general should die on the field of honor!" Napoleon, too, preached something he didn't practice!

Volta made many more valuable contributions to the electrical science and as said before, his name has been made immortal by adaptation in the term given to the unit of electrical force or pressure—*the volt.* He lived until 1827, six years after Napoleon himself had died at St. Helena, and long held aloft the flaming torch of science. Before he died, he saw the torch grasped by many workers and finally reach a new and greater brilliancy in the hands of the greatest man who ever walked across the stage of experimental philosophy, the humble, pains-taking, genius son of a poor English blacksmith, Michael Faraday.

Before Faraday appeared, Volta's discoveries had opened the door to fame for many men. Volta had announced his findings in a letter to Sir Joseph Banks, then President of the Royal Society in London. Banks told the news to William Nicholson and to the latter's young friend Anthony Carlisle, who later became a distinguished surgeon. Nicholson and Carlisle on April 30, 1800, set up the first voltaic pile made in England and by May they had shown that water can be decomposed into the gases hydrogen and oxygen by merely passing a current through it.

William H. Wollaston immediately seized on

this experiment as a test to show the identity of voltaic electricity and frictional electricity. He decomposed water with either arrangement and correctly assumed that the fluid from the pile was "less intense, but produced in much larger quantity." Later Van Marum and Pfaff used Volta's pile to charge batteries of Leyden jars. In 1803 Ritter made a rechargeable battery with platinum electrodes but not until 1860 did Gaston Planté begin the modern development of storage batteries with his lead cell.

The decomposition of water by the electric current made a great impression on Davy, the Professor of Chemistry at the Royal Institute in London, an organization formed a few years before by an American, Benjamin Thompson, better known as Count Rumford, who first demonstrated experimentally that heat is a mode of motion. This young Professor Davy became Sir Humphry Davy. He showed that the liquid in voltaic piles or cups would not work if it were pure water but that it must be something capable of oxidizing the zinc. He also discovered that the strength of the battery depended upon the amount the zinc was oxidized. That is, a purposely made acid solution had more effect than mere impurities. Hence he concluded that the chemical changes in the pile some-

how were the cause of the electrical effects.

"Chemical and electrical attractions," he declared in 1826, "are produced by the same cause, acting in one case on particles, in the other on masses, of matter; and the same property, under different modifications, is the cause of all the phenomena exhibited by different voltaic combinations."

It should be recorded here that Volta had originally compiled a list called "the voltaic series" of all the metals and their voltaic effects, although copper and zinc were the ones he used. He seems to have looked upon the corrosion of the zinc as in no way connected with the development of electricity but purely an incidental effect rather to be expected because nothing lasts forever. Since Volta, John Brown has shown that the voltaic series is badly upset in an atmosphere of gases other than air.

The attention of chemists was directed to the cell and, of course, the science of electrochemistry began with the decomposition of water electrically, as above recorded. Decomposition of other compounds followed right along. The chemists fought and wrangled over various theories of what was happening in the voltaic pile or cups while the electricians soon were startled by a series of momentous discoveries.

It will be remembered that up to Gilbert's time the simple phenomena of magnetic attraction and of electric attraction were considered to be the same thing although St. Augustine had wondered why the lodestone and the amber didn't act on the same kind of substances. After Gilbert, although the two phenomena had been separated, the general thought of a relationship did not die out. When Franklin identified lightning with electricity, it was possible to look back in the "Philosophical Transactions" to 1735 when a tradesman of Wakefield, England "having put up a great number of knives and forks in a large box, and having placed the box in the corner of a large room, there happen'd in July, 1731, a sudden storm of thunder, lightning, etc., by which the corner of the room was damaged, the Box split, and a good many knives and forks melted, the sheaths being untouched. The owner emptying the box upon a Counter where some Nails lay, the Persons who took up the knives, that lay upon the Nails, observed that the knives took up the Nails." They were of steel, of course, and no doubt magnetized by the lightning discharge.

Franklin's knowledge of such happenings as this led him in 1751 to attempt to magnetize

sewing needles with sparks from Leyden jars and strangely enough, with some success. But the experiment couldn't be done with certainty. Nevertheless, it was an indication of some connection between magnetization and electricity.

In 1807 Hans Christian Oersted, Professor of Natural Philosophy at Copenhagen, set himself to see what connection existed, but for thirteen years he made no progress. Then the inevitable accident occurred. While lecturing before a class he had his attention called to the movement of a compass needle on his lecture table whenever a current was made to flow in a near-by conductor. Heretofore, in his search, he had been dealing with a stationary electric charge or a voltaic pile not connected in circuit, expecting the latter to show an attraction at the ends something as a magnet does. Such effect had been discovered by Romagnosi of Trent in 1802, but Oersted found that whatever happened was very weak and when the pile was placed in circuit the attraction disappeared altogether.

After the class room incident he began to investigate the effect of the flowing current itself. For a long time he set the compass needle across the wire thinking it would align itself. Then he decided to try it along the wire and immediately

there was a deflection with the needle coming to rest across the wire. A connection or an interaction between the two forces was proven. With the compass above the wire, the needle turned one way and with the needle below the wire, it turned the opposite way. It seemed as if the direction of the magnetic force encircled the conductor.

André Marie Ampère, whose name is given to the unit of current, the ampere, one week later showed that two parallel wires carrying current and free to move, attract each other if the currents are in the same direction and repel each other if the currents are in opposite directions. He also was the first to discover that not only did a wire carrying current attract a magnetic needle but, also, the needle would attract the wire. Ampère's work is amazing in view of the fact that at the age of eighteen he was almost a hopeless idiot, partly from overtaxing his brain in intense study and partly because of the death of his beloved father in the revolution of 1793 in France.

François Jean Arago, who, among other great endeavors, classified lightning as of three kinds —forked or jagged, as usual; sheet lightning which is really a reflection on the clouds; globular or ball lightning in the form of a ball of fire

which moves along slowly and bursts,—found that if a current passes through a wire, the wire will attract iron filings to itself as long as the current flows. The filings set themselves around the wire, thus indicating the presence of an encircling magnetic field. Davy and Arago independently showed that by coiling the wire around a bar of iron, the iron would become a very powerful magnet as long as the current flows. This is the electromagnet. If the bar were of steel, they found that it would retain its magnetism to a great extent, even after the current ceased to flow. Thus permanent magnets could be made and experimenters no longer depended upon the lodestone.

Joseph Henry of Albany, N. Y., developed the electromagnet to lift hundreds of pounds but his contribution to knowledge in this field came from his discovery that at the moment of breaking the circuit in which such a coil is included, there would be a tremendous "extra" current sufficient to cause a spark to jump the break in the circuit, a phenomenon known as "self" induction. Sparks made in this manner were used to light gas jets.

A relationship between electricity and magnetism having been established, one recalls the old thought of a relationship between heat and

electricity, as intimated by Nollet and by Franklin. In 1822 Thomas Johann Seebeck of Berlin showed such a connection. He demonstrated that if copper and bismuth half circles were soldered together into a ring and the ring heated at either junction of the two metals, a current would flow. This started the study of thermoelectricity. In 1834 Peltier established the converse of Seebeck's effect, that a current flowing in the ring would cool one junction and heat the other.

Then came G. S. Ohm of Bavaria who in 1826 established the law which bears his name, that the amount of current flowing in any closed circuit is proportional to the electrical pressure or force (voltage) and inversely proportional to a constant which depends on the cross section, the length, and the material of the wire. This constant is called the "resistance" of the wire. It was 22 years before this quantitative study made by Ohm was recognized as meritorious, and then he was made a Professor, considered a high honor in Germany, but he lived only five years to enjoy his title. To-day his name is given to the unit of resistance, or opposition to current flow, and with Ampère and Volta, among others, he has achieved immortality in the language of electricity.

Faraday, Joule and others dimly saw later a relationship similar to Ohm's Law applying to the magnetic circuit but not until 1873 did Rowland express it. Bosanquet and Oliver Heaviside introduced the modern terms, so we now calculate the relation between magnetic flux, magnetomotive force, and reluctance in exactly the same way as between current flow, electromotive force, and resistance in the electrical circuit.

The same year that Ohm published his remarkable paper an Italian, Leopoldo Nobili, took up Galvani's experiments with frogs' legs and showed that when the nerve and muscle were connected by a water contact, a very slight current would show on a sensitive galvanometer, and continue for many hours. He even made up batteries, using frogs' legs, showing the presence of animal electricity. Long afterwards Du Bois Reymond obtained currents from his own muscles by dipping both forefingers into separate cups of salt water connected together through a galvanometer. Then when the muscle of either arm was suddenly contracted, a current would flow from the contracted to the uncontracted muscles. Dewar proved that when light falls on the retina of the eye, there is an electric current in the optic nerve; Buff de-

tected electrification produced by plant life, the leaves being positive and the roots and juicy parts negative; and Humboldt tells of lively battles between the electric eels and wild horses forced into swamps. Poor old Galvani's point of view has been well sustained but, of course, all this has nothing to do with the phenomenon soon afterwards known as animal magnetism, then called mesmerism, and afterwards hypnotism.

With these discoveries we have come a long way. It was with a knowledge of most of these facts that Faraday began his work. Let us look at what they were that we may better appreciate him. First, the number of ways of getting electricity had been greatly multiplied. We had friction machines, voltaic piles, chemical batteries, frogs' legs, heating the junction of two metals. A relation had been established between electricity and magnetism, and a compass needle would indicate current flowing in a wire, thus giving the electric indicator known as the galvanometer, simply a coil of wire with a compass needle inside, as modified by Cumming and Schweigger from Ampère's original idea of a simple needle above a wire. Properly devised, of course, the amount the needle was turned served to measure the strength of the current in

the coil, as Pouillet was to show in 1837. Later this was improved by D'Arsonval. Our electric meters to-day are practically this galvanometer in portable form.

Then, too, a way of making strong magnets had been developed and the weak lodestone was no longer the sole equipment of a magnetic laboratory. Galvanometers, we might mention, were also called "rheometers" from the Greek "rheo" meaning "flow." This terminology became quite common but we have only one survival of it now, in "rheostat," a resistance which can be varied to cut down the flow of current.

Faraday thus had a plentiful source of electricity, a device for the measurement of electric current, a knowledge of a relationship existing between electricity and magnetism, some idea of chemical action being influenced by the electric current, and means for making strong magnets, as well as the quantitative knowledge for simple calculations as provided largely by Ohm.

The laboratory of the Royal Institution at that time contained Leyden jars, galvanometers, Davy's immense battery of 600 Volta jars as improved by Wollaston, lodestone, compass needles, some iron, and bare wire, for the use of insulated wire seems to have been due to

Joseph Henry, who first wound coils with it. There were also some chemicals.

Compare that, as you read the next chapter or two, with even a schoolboy's meager equipment to-day or with the splendid equipment of the U. S. Bureau of Standards.

CHAPTER VII

THE BLACKSMITH'S SON BECOMES A VALET

"The paths of glory lead but to the grave."
—Gray, "Elegy Written in a Country Churchyard."

SOMEHOW Michael Faraday seems like a link between the remote past and the present age. He was born in 1791, the same year as Samuel F. B. Morse, and one year before the invention of the cotton gin by Eli Whitney. He was a boy of eight when Washington died and yet he outlived Abraham Lincoln more than two years. While he was still a baby the reign of terror was on in France, the carts were rumbling in the streets and heads were falling in the public square. He was five when Napoleon crossed the Alps and twelve when the Little Corporal became Emperor. History was being made only twenty miles away across the English channel but the only way he or anyone else heard of it was through letters, messengers and travelers.

When he died in 1867 cables had been laid under the Atlantic and telegraph wires spanned the countries. He saw electricity put to work.

Faraday had little schooling. In fact, he taught himself to read and write. His father was a blacksmith and early in life Michael was apprenticed to a bookbinder. He read widely and attended lectures at the Royal Institution given by the then famous chemist Sir Humphry Davy. In 1831 Davy made him a laboratory assistant at the Institution and shortly afterwards took him abroad where he met Volta, Ampère, Humboldt, Cuvier, Gay-Lussac, and many other men whose names dot the pages of science. In his diary he records without particular interest, a glimpse of Napoleon "sitting in one corner of his carriage, covered and almost hidden by an enormous robe of ermine, his face overshadowed by a tremendous plume of feathers, that descended from a velvet hat."

This trip with Davy, lasting nearly two years, was the only time Faraday ever left England except for vacations in Switzerland late in life. It was not a particularly pleasing experience although his joy was great in seeing the sea for the first time; in his three trips to Vesuvius, two of them while the volcano was active; in being shown a glowworm; and in meeting men of

note who were to be his friends for many years.

At Florence he studied Galileo's own crude telescope and with the rays of the sun condensed by the great burning glass of the Grand Duke of Tuscany loaned to them by the museum, he and Davy made the "grand experiment" of burning a diamond in oxygen, and they found it to be pure carbon just like the coal which only six years before in Wilkesbarre, Pa., Judge Jesse Fell had publicly demonstrated could be burned in the barroom fireplace, attracting mobs from far and near to see black rocks burning merrily.

He helped Davy in experiments on a new and strange substance made from ashes of seaweed, which the French scientists had been fruitlessly investigating for two years and Davy, to their chagrin, with characteristic genius almost instantly guessed its nature. It was iodine.

He went shooting with Davy and De la Rive. He was with his chief constantly, experimenting, meeting scientists, studying industries, visiting museums and laboratories. Yet he was not permitted to eat at the same table with Sir Humphry and Lady Davy and his position in the family was almost intolerable.

He had been engaged as Davy's laboratory

assistant but the latter's valet at the last moment declined to take the long trip and, as Faraday wrote to one of his intimate friends, "in the short space of time allowed by circumstances another could not be got. Sir H. told me he was very sorry, but that, if I would do such things as were absolutely necessary for him until he got to Paris, he should there get another. I murmured, but agreed. At Paris he could not get one." The same condition existed at Lyons, Montpelier, Genoa, Florence, Rome, "and I believe at last he did not wish to get one."

Faraday appreciated that Davy did everything he could for himself but, he writes, "Lady Davy is of another humour. She likes to show her authority and at first I found her extremely earnest in mortifying me." He tells of the quarrels between Lady Davy and himself after each of which she lost ground and her manner became milder. " 'Tis the name more than the thing which hurts," confesses the young scientist, and his experience so discouraged him that he was tempted to return home to his old profession of bookseller "for books still continue to please me more than anything else."

But all things have an end and to Faraday's great delight the journey was cut short by more

than a year and they returned to London in April, 1815.

In May, 1821, Faraday became superintendent of the house and laboratory of the Royal Institution but his salary remained $500 per year with two rooms, coals and candles furnished. On June 12 of the same year he married. His devotion to his wife through their forty-six years together was intense, perhaps greater than his striking devotion to his strange religion. It is recorded that on one visit to Switzerland in 1841 he walked the 45 miles from Leukerbad to Thun over the Gemmi Pass in one day that he might not be absent from her side on Sunday.

Davy suffered paralysis in 1825, a year after he, as President, had unsuccessfully opposed Faraday's being elected a Fellow of the Royal Institute. He died in 1829. As Davy's biographer has said, the jealousy manifested by his opposition to Faraday's election "is one of the most pitiful facts in his history."

In 1825 likewise Faraday became Director of the Laboratory of the Institution and held that place until his death. Many honors were thrust upon him but all during his life he declined every other position including the Presidency of the Institute and the Presidency

of the Royal Society, the sole exception being a special professorship at the Institution created for him for some technical reasons. He refused to be knighted and the newspaper quip that Far-a-day must be near-a-knight fell flat. He remained simply Michael Faraday in life and in death. There is no other marking on the stone which denotes his final resting place.

For a while Faraday undertook professional work aside from his duties at the Institute, doing analyses, expert work in the courts, and other investigations to eke out the slender income mentioned above, but in 1830 he decided he could not spare the time from his researches. In that year he had received over $5000 for this professional work and, with his growing fame in the next few years might easily have become financially independent, but he chose otherwise.

He gave a series of twenty lectures in chemistry each year at the Royal Academy at Woolwich for which he received $1000 a year and this extra work he considered only because it was to him in the nature of relaxation. He had his wife to support, his aged mother was entirely dependent upon him, and in addition there were many calls for private charity to those whose need he knew. In order to send his younger sister to boarding school, he at one time

found it "absolutely indispensable" to deprive himself of dinner every other day.

In connection with his utter disregard of money, it may be said that one of the tenets of his religion was that it is wrong to save money for "the Lord will provide" and, sure enough, in Faraday's case, at least, He did!

If all of Faraday's purely electrical work had been destroyed, his fame would still be secure as a master chemist. He was the first to condense gases to liquids by pressure, giving us the information by which low temperatures are reached and on which modern refrigerating plants are based. Both with his chief and after Davy's death, he advanced the subject of electrical decomposition of substances and gave us quantitative knowledge of it resulting, among other things, in the electroplating industry started in 1840 and electrotyping, an idea stumbled on by De la Rue in 1836 and Jacobi in 1839.

His technical endeavors and achievements in the manufacture of steel, of glass for optical purposes, and his work in the polarization of light can be appreciated only by fellow workers in those fields.

The thing which turned Faraday from chemical work to electrical research was Oersted's

discovery, mentioned above, of the effect of a current on a magnetic needle. Faraday reasoned correctly that if a current causes a needle to move in that way, a magnet should cause a wire carrying current to rotate. After much experimenting he finally succeeded in so hanging a conductor that it would rotate about a magnetic pole. This gave rise to the first electric motor, and that old dream of Peregrinus had come true. Electric motors have taken many burdens from the backs of both men and beasts.

Faraday gave us the language and terminology of electricity. With the help of his close friend, Rev. W. Whewell, he coined such words as electrodes, electrolyte, ion, anion, cathion, paramagnetic, electronic. He devised the idea of "lines of force" and "fields of force" by which students visualize the conditions surrounding coils and condensers. He gave us the details of theory which made electricity an exact science instead of a disconnected series of haphazard and mischievous events. "His principal aim," said Helmholtz in the Faraday lecture of 1881, "was to express in his new conceptions only facts, with the least possible use of hypothetical substances and forces. This was really a progress in general scientific method, destined to

purify science from the last remains of metaphysics."

His experiments and discoveries were so numerous that merely the titles of his important original papers take up page after page of the record. We can speak only of those few with which the progress towards radio has to do.

He established the laws of magnetic induction. Basing his work on that of Oersted and Ampère, he soon determined that the magnetic field surrounding a wire carrying current would "induce" or set up a current in another wire near by if (A) either wire is moved so that the magnetic field surrounding the current-carrying wire cuts across the second wire or (B) if the strength of the magnetic field is varied and both wires remain stationary. Of course, the easiest way to vary the field is to start and stop the current in the first wire.

The discovery of the first action (A) led him to invent the electric generator in which many wires are moved through a strong magnetic field, first obtained by the use of permanent magnets (the magneto) and afterwards by the use of electromagnets (the dynamo). Faraday built many crude types of generators and thus we had a new method for the production of electricity to add to the frictional devices, bat-

teries, frogs' legs, and thermoelectric couples.

His discovery that stopping and starting the current in one wire caused a current in the second near-by wire (B) led him to invent the induction coil so much used for sparking purposes. This afterwards was improved by Ruhmkorff, for which he received the French grand prize in 1864.

Later came the transformer which differs from the induction coil only in omitting the current interrupter in the primary circuit and feeding alternating current instead of direct flowing or battery current. That is, instead of stopping and starting the current in the first coil by making and breaking the circuit, it is done automatically in the generator.

Faraday discovered alternating current and to-day in the medical profession, it is usually termed Faradic current. In his early researches, endeavoring to generate electricity from a magnet, Faraday plunged a bar magnet into a coil of wire and then pulled it out again quickly. He found a current was induced in the coil in one direction as the magnet entered and in the other when the magnet was pulled out. When the north pole was plunged in, the current was the reverse of what it was when the south pole was plunged in the coil. So when a

wire passes in front of a north magnetic pole the current induced flows one way in the wire and when it passes in front of a south magnetic pole, the current flows the other way. Between the poles it dies down to nothing.

All ordinary generators deliver this alternating current. They have to because there are always two poles to any magnet and the magnet field extends from one to the other. The rate at which the current reverses will depend on how fast the wire passes from pole to pole.

It was soon discovered that if the connections from the generator are reversed at the instant the direction of current in the rotating wire reverses, the output current will all flow the same way in the wires connected to the machine. This reversing device, called the commutator, makes possible the delivery of direct or continuous current, all flowing in the same direction and a machine arranged this way is called a direct current generator although it is an alternator with a commutator used as a rectifier.

Of course, if only one wire is revolving between the poles of the machine the current, while direct (if a commutator is used) will die down and build up again. It will "pulsate."

To remedy this a large number of wires connected together are used, successively cutting the magnetic field so that as the current in one wire is dying down that in another is building up so the resulting current is fairly steady, but no matter how many wires there are and how many poles, there is always a little "ripple" in the current. That is why there will be a "hum" on a radio set used on direct current without a filter, but it is not so hard to filter out this "ripple" as it is to get rid of the much greater variations on alternating current lines.

More and more as we study Faraday's work we see how much he opened up to us. To-day books are being written and much is being said of the "new chemistry," yet Faraday before 1840 had said, "I must confess I am jealous of the term *atom;* for though it is very easy to talk of atoms, it is very difficult to form a clear idea of their nature, especially when compound bodies are under consideration."

This lends substance to a later remark, "All the facts show us that the forces termed chemical affinity and electricity are one and the same," an idea similar to Davy's speculation. Faraday went further, however, and in 1846 wrote that an ultimate atom may be nothing else than a field of force—electric, magnetic, and

gravitational—surrounding a point center, and this thought is not far distant from the precise idea of modern electron theory.

To radio, the importance of Faraday's researches can hardly be magnified. He discovered the relative merits of different dielectrics used between the plates of a condenser and tabulated the dielectric constants which indicate their merits. He founded the electromagnetic theory of light in his famous paper, *"Thoughts on Ray Vibrations."* Light and radiant heat, he suggested, may be transverse vibrations along the lines of force. If the existence of an ether is admitted, wrote Faraday in 1851, it might be the vehicle of magnetic force. Along the lines of magnetic force, he continues, there may be a dynamic condition analogous to the electric current and, in fact, "the physical lines of magnetic force are currents."

These thoughts of the great English scientist are the beginning of the conception of those ether waves we call radio and on this theory of Faraday's the great Scotch mathematician, James Clerk Maxwell, built his monumental treatise that guided the German, Hertz, to the actual experimental establishment of Hertzian waves, which the Italian, Marconi, and others seized on for the medium by which communica-

tion between distant points could be established without wires.

Even in early life Faraday was plagued by loss of memory and as he grew older this trouble occurred frequently. At times his mental condition compelled a complete cessation of his activities for several years. Towards the close his powers of mind began to fail completely but death came before his condition became painful to his friends. His last days were spent at Hampton Court in a pretty little house on the Green in front of the Palace, offered to him by Queen Victoria and gladly accepted "after the place had been put in repair."

The queen was always kindly disposed towards Faraday but on one occasion was the innocent cause of his being "kicked out" of the religious body of which he was such a devout member and elder. It seems that one of their strict requirements was attendance every Sunday at meeting and Faraday was guilty of being absent once when upon command of the queen he took luncheon with her at the palace on Sunday. Whereupon he was promptly deposed as elder and dropped as a member, though reinstated some years later.

That with all his genius Faraday visioned the adaptation of electricity to modern life may

well be questioned. He saw the possibilities and saw much accomplished. During his allotted span of 76 years he saw the steam engine developed and put to work in mills, on railroads, and on the sea. He saw coal come into general use as a fuel. He saw the telegraph developed and stretched across the continents and the cable span the ocean beds. He saw the early telephone experiments but did not live to see Bell's invention, although many years before he had himself found that a vibrating armature in front of an electromagnet affected the current in the magnet coil, and on this fact the telephone receiver is based. He knew the electric motor and the electric generator for he had made them, and the electric arc light was familiar to him because Davy invented it in 1800, but none of these three things was used to any extent before his death.

He saw photography developed and in this he had a part. He saw the gas light succeed the candle and the lamp. He saw hospitals arise and the growth from the torture of amputation with merely a heated knife to the mercy of unconsciousness. Dreams he must have had, wonders there were on every hand, and part of them he was. He lived when mental giants were no rarity and he was peer among

them. As he sat in the western window of his home watching the sunset and his loving wife called his attention to a rainbow across the sky, almost his last words were, "He hath set His testimony in the heavens."

At his own request his funeral was of the simplest character. His body was conveyed to Highgate cemetery by his relatives and deposited in the grave, according to the practice of his sect, in perfect silence.

Faraday was not only the greatest of experimental scientists, teachers, and lecturers but he was also the last of his race. When he died in 1867 every man whose work has been discussed was dead except M. De la Rive. Rumford died in 1814, Fabroni in 1822, Volta in 1827, Wollaston in 1828, Davy 1829, Seebeck 1831, Ampère 1836, Oersted 1851, Arago 1853, Ohm 1854. De la Rive lived only to 1873.

A new group had sprung up, the famous mathematical electricians of the middle of the nineteenth century, who developed the study of physics and physical chemistry and made calculus the court language of science. By all odds the most outstanding of them in the electrical field was James Clerk Maxwell, head and shoulders above the crowd.

CHAPTER VIII

A PROPHECY THAT DIDN'T PAN OUT

"There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy."
—SHAKESPEARE, *Hamlet* I:5

THE world of 1791 and the world of 1867 may well have been on different planets, if one were to judge by the events which had taken place between those dates. But viewing these two worlds unattached, it is hard to see striking differences except in thought. Great discoveries had been made but few had been utilized. Great wars had been fought but the *status quo ante* had been restored by time.

France at the earlier period had been an empire, passed through a bloody revolution and many wars and still at the later period was again an empire. In America, at the end of the Revolution, the states, more or less at swords' points with each other, had united in form. The War of 1812 had been fought and won, the Civil War had ended, the states reunited and still at swords' points. Some issues had been settled by

force of arms, changing mental conditions rather more than physical conditions. Men had learned to live together in the New World and there was more tolerance, perhaps. And then again, perhaps not!

The condition of the individual and of the state had changed but little in physical matters. Communication was easier but not developed. Transportation was less fatiguing but not undergone for pleasure. There was but little power. Industry was in baby clothes. Men dressed somewhat differently but women sat by the fireside. Both ate largely at home of products direct from the soil.

Illumination had progressed little, although the gas light was seen on the streets. Cities had grown little. Luxuries had not become popular. Magazines were rare and books uncommon. The theater was about the same. The church had not changed at all. The rich were rich in moderation and the poor were definitely poor. It seemed as though a period of preparation had been gone through and the world was waiting for the sunshine of industry. From Washington to Lincoln it appears that the struggle among men was a struggle of minds, a testing of ideas, a laying of foundations. From Lincoln on, the struggle was of the hands, of

accomplishments; a materialistic struggle for the establishment of enterprise and wealth.

For the first half of the century men builded for the future. For the last half they built for the immediate present. They were less interested in finding new things than in using the multitude of discoveries at their hands. They commercialized the past.

Electrically in 1867 the advance had been mostly in the laboratory. Morse's telegraph, among others, had been made successful. The cable had hardly had time to prove its worth. Now came Bell with the telephone and was laughed at, but it was ultimately made commercial because of industrial growth. The idea of speed and convenience was translated into dollars and cents.

Transportation by means of the railroads became less a matter of passengers and more a means of moving freight. The little local factory could stretch out, not only to get raw materials cheaper but to reach wider markets. Industry was becoming nationalized. Factories didn't have to be alongside of customers. Growth was largely limited by power and concentrated power gave rise to the thought of distributing power just as products had been distributed. Then came dreams of electricity, but

it was 1892 before we had power distributed over the electric wire.

The story of progress is the story of power. Power gave us industry, transportation, communication. Power gave us electricity as a useful thing. We are apt to think of electricity as power but really its great field has been in making power available. Something is required to drive the machines which generate electricity. That something is the steam engine. As long as power was used where it was made, the engine itself would give the power and there was no great use for electricity commercially. When power had to be transmitted away from where it was generated, then electricity stepped in and on the other end, the receiving end, men began to do things electrically.

Electricity owes its importance to the nationalizing of industry and the growth of cities. Fortunately, when the world was ready for electrical power, the laboratory had the materials suited to the finished product and here we have the argument for pure science and science research. The thing discovered to-day may be of no present use, but to-morrow the world may need it badly. As Franklin once remarked on this subject, "What use is a baby? Why, it may grow to be a man!"

Radio has been ready these many years. When Faraday died we had the battery, the condenser, the coil, the transformer, the electric circuit, the theory, the idea of action at a distance through the electromagnetic effect. We did not have the utilizing idea, the thought that this combination could be used to produce communication. No one wanted to communicate without wires. Although the telegraph was a success, yet even when the telephone came along no one wanted to communicate *with* wires. Men couldn't see the need and there was no need. The need had to be created and even to-day there are many who prefer the one cent postcard as being cheaper, less troublesome and more certain.

But the torch so long held aloft by Faraday did not lack for bearers. There were still men who wanted to know why, whether the answer brought them a reward or not. Even while he lived, another hand had come to his assistance and an able-bodied helper he proved to be, a fellow countryman named William Thomson, long afterwards known as Lord Kelvin. Thomson's work on Faraday's theories was important for its own sake, but from the standpoint of radio was most important in that it inspired another Cambridge man, James Clerk Maxwell, to take up the matter of how this propagation of

electric or magnetic force takes place through space. Always that has been the question—action at a distance. What was there between the thing acting and the thing acted upon that communicated the action?

Maxwell differed much from Faraday. He was almost the exact opposite in nature and in training. He was born in 1831, son of a landed proprietor in Dumfriesshire, rich but respectable. Educated at Edinburgh University and afterwards at Trinity College, Cambridge, his bent was mathematical physics. Where Faraday hated mathematics, Maxwell loved it. Gifted with an imagination second only to Faraday himself, he had been profoundly impressed by Faraday's theory of lines of force and so inspired by Thomson's visualizing of this theory that he attempted to make it mathematical, to express Faraday's concepts in mathematical symbols that they might be adapted for general reasoning and comparison with known physical actions. His final desire was to devise a mechanical conception of the magnetic field. In his success he owed much to the analytical methods devised by the French mathematician, Joseph Louis Lagrange.

Maxwell's concentration and unending application is indicated by the time and manner of

his exercise. His biographer tells us that this was taken usually about two o'clock in the morning. He would run along the upper corridor of his lodging house, then down the stairs, along the lower corridor and up the stairs perfectly unconscious of the disturbance he was creating, until his fellow lodgers, encamped behind their doors, threw boots, brushes, and pillows at him and in his path.

Happily Maxwell had opportunities for personal contact with Faraday who was living in retirement at Hampton Court where in 1857 he was speculating on whether the velocity of propagation of magnetic action was of the same order as that of light. Maxwell proved mathematically that not only was it of the same order but that it was exactly the same amount. This was so striking that he did not hesitate to assert the identity of the two phenomena. "We can scarcely avoid the inference," he writes, "that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena."

The inferences from this statement caused the scientific world to gasp. It is what is known as the electromagnetic theory of light. In effect, it says that light, electric currents, and magnetic fields are all wave forms in the ether

of space. Followed to its conclusion, it would mean that the electric current is not a phenomenon in the metal of the wire itself but in the space around and inside the wire and guided by it. Priestley's question was answered.

Lord Kelvin to his dying day could not accept this and for a time many of Maxwell's colleagues disagreed with him. Most of them misunderstood his conclusions and paid no attention to Maxwell's work until after the experiments of Hertz. The magnitude of the argument that ensued prevented any progress with the theory for years. Maxwell retired to his estates in Dumfriesshire and occupied himself with writing that monumental treatise "Electricity and Magnetism" with which his name will ever be associated.

Maxwell's sole thought seemed to be to disseminate the ideas of Faraday and he paid little attention in this volume to the conclusions he had himself drawn from them, and the contributions he had himself made to their final proof.

He died soon afterwards in his forty-ninth year; the torch flickered for a moment, and never seemed so bright again. It was to go on a long, long journey never again to rest in England where it had blazed for fifty years, save for

a few brief moments many years afterwards on its final journey to America.

It was now 1879. Bismarck had guided Germany through a victorious struggle with the French and was still in power, although William I was Emperor. The latter had been dangerously wounded by an assassin. Pope Pius IX and King Victor Emmanuel had both been dead a year. Jules Grévy was president of the Republic of France; Rutherford Hayes was the nineteenth president of the United States; Gladstone and Disraeli had been bobbing back and forth and the former was about to replace the latter again as the premier of England.

Five years more elapse before a young student of Helmholtz, Heinrich Rudolf Hertz by name, who was born in Hamburg, Feb. 22, 1857, and lived only 37 years, a graduate of the University of Berlin, early a civil engineer, and finally a Professor (1889) at Bonn University, was to grasp the torch and attempt to justify the Maxwell mathematics theoretically. This not working out so well, he attempted verification by direct experiment and in 1886 noticed an effect which formed the starting point and, in reality, the end of his search.

Hertz noticed casually while working on

something else, that when a piece of copper wire bent in the form of a rectangle with the ends forming a short air gap, was connected by a wire with any point of a circuit which included an induction coil and spark gap, there would also be a spark in the wire air gap when there was one in the spark gap. He rightly reasoned from this the finite velocity of propagation of electric potential along wires which allowed one side of the gap to reach a higher potential than the other at the same instant.

He found further that the spark would occur even when the rectangular wire, which he called a resonator, was not connected to the other apparatus! He proved that this was caused by the resonance of circuits, the phenomena by which we now tune in our radio sets. Hertz had made a monumental discovery because all that had been needed to test the Maxwell theories of the propagation of electric waves in space was some way of detecting their presence and knowing it. The Hertz resonator gave the required detector. That was his great contribution to science. Others had had detectors before him, as we shall see, but were not sure of it and did not go on.

Hertz undoubtedly was not aware that in 1870 Wilhelm von Bezold had anticipated his

discovery of the transmission of electric waves along wires and had determined the speed. Probably Hertz did not know that back in 1842 Joseph Henry noticed that the inductive effects, as he called them, of the Leyden jar discharge could be observed at considerable distances by means of a coil and a galvanometer, although Henry strangely thought that it was a spark effect and made a note to see some day if a spark from flint and steel behaved the same way. He noticed that sparks were set up in distant circuits. He also magnetized steel needles by the current in a coil several hundred feet away. He thought the action was ordinary Faradic induction. One of his other experiments was to connect a large plate to the electrical machine and a similar plate three floors below was found to be electrically charged.

Many others noticed effects we now know were due to radio but in almost every case ascribed them to induction. Prof. D. E. Hughes in 1879 actually anticipated much of Hertz's work and felt that it was a new effect, but many of his learned colleagues believed it was induction and discouraged him from publishing his work.

Hertz had the advantage that he knew what he was doing. He set up a radiating device

which was merely two large plates forming an air condenser, connected to an induction coil, each plate having a knob so that a spark gap was formed between them. Fitzgerald (1883) had previously proposed to start electric waves in this way. With his resonator, Hertz detected the transmitted high frequency ether waves. Transmitting them simultaneously through space and through a wire, he found the ratio of the velocity in air to the velocity in the wire, the former being shown to be finite and the same as that of light. Much to Hertz's astonishment he found the above ratio to be as 7 to 4, the velocity in wires being the smaller. Afterwards, however, the cause was discovered to be interference from waves striking the walls of his small laboratory. L. de la Rive and E. Sarasin of Geneva, suspecting this, experimented in a large hall and in 1891 found that in wires and in space the velocity was the same.

Hertz's modesty in success was remarkable. He stated that if he had not happened to have succeeded, Sir Oliver Lodge, who was on the same quest, would certainly have done so. But as it was, the young German continued his investigations even further and soon demonstrated that these ether waves, just like those we call light, can be reflected, refracted, diffracted,

and polarized. He, of course, made no attempt to utilize or commercialize his discoveries but gave them freely to the world. His researches were all presented between Nov. 10, 1887, and December 13, 1889. He used a wave length of about 5½ meters. Later Righi and Lebedew got down by stages to 1 cm. wave length.

These important discoveries of Hertz cause us to turn back for a moment to the strange prophecy of Johann Kruger, Professor of Philosophy at Halle in 1743, who is famous for the saying that philosophy is "trying to understand what you do not see, and not believing what you do." His students wanted to know the use of all this electric stuff.

"What's the use of bugs, fleas and grasshoppers?" was his answer, recalling Franklin's baby comparison of later years. "God only knows what the ingenious heads of our time will get out of it all.—If it must have some practical use, it is certain that none has been found for it in Theology or Jurisprudence, and therefore where else can the use be than in Medicine?"

But he believed that the "Germans have laid the foundation, the English will erect the building, and the French will add the decorations." In the general field, this is superficially true as can be recognized by recalling Von Guericke,

Helmholtz, Hertz; Faraday and Maxwell; Coulomb, Nollet, Arago. But in many ways it misses the mark. The very foundations of all rest on Gilbert, Dufay, Musschenbroek, Franklin, Galvani, Volta, Oersted, none of them Germans. And the work of such French scientists as Dufay, Ampère, and Fresnel are far from mere decorations. In radio waves, Hertz did lay the foundation, thanks to the excavation work of Faraday, Fresnel, and Maxwell, but an Italian, Marconi, built the building, even though the Americans, Loomis and Dolbear, and the Englishman, Hughes, may have helped to show him how.

In the next chapter we get acquainted with Fresnel who lifted scientific speculation to as great a height as Faraday reached with experimental research.

CHAPTER IX

LOOSE ANKLES

"With the fairy tales of science, and the long result of Time." —TENNYSON, "Locksley Hall."

THERE is no straight and narrow path to truth but just the broad stretches of dark and tangled underbrush through which a great crowd is pushing its way.

All around the horizon is the goal. The whole surface of the ground must be cleared and so the feverish struggles of each little group leaves much work to be done on either side. Where one strenuous, able pathfinder makes a trail deep into the unknown, others follow to broaden it and link it up with the neighboring trails. These last overlap each other. They work together. And then in behind come those commercial souls, who use the cleared space, sell the land and water rights and move on to the next killing.

Faraday was a pathfinder and when he fell, Maxwell and Hertz carried on. But in the half

century or so between the elementary lines of force and the demonstration of ether waves many discoveries were made on both sides of the trail. Other discoveries of Faraday were worked up to where they became commercialized.

In the case of the electric generator, Faraday's work was done when he evolved the principle and showed a working model. Wheatstone and Cooke in 1845 got a patent for using electromagnets to create the field of force in which the wires turned. Then in 1848 Jacob Brett suggested that part of the current generated by the machine be sent back through the coils of the field magnets so that the machine would be complete of itself, needing only an engine to turn it. It was not until 1867 that Werner Siemens used the term "dynamo electric machine" which soon was shortened to "dynamo" but somehow in these later years that has fallen into disuse and "generator" has taken its place. Meanwhile Pacinotti, Professor of Physics at Turin, published in 1864 a description of the commutator, mentioned before as a device to smooth out alternating current to continuous current.

While one group was thus busy with the machine to generate electric power, others were

trying to learn more about electricity itself. Charles Wheatstone was one of these and a most extraordinary man he was. He lived in Gloucester, England, and made musical instruments. Becoming interested in the measurement of small intervals of time, he set out to measure the duration of the flash given by an electric spark and about 1834 was successful by means of a mirror rotating at very high speed. This feat caused him to be appointed Professor of Physics at King's College, where, with Cooke, as mentioned above, he received a patent on one type of electric generator.

They also received a patent for "sounding alarms in distant places, by means of electric currents transmitted through metallic circuits," although Joseph Henry in America had long before had an electric bell at his home in Albany which he could ring from the Albany Academy building some miles away. Wheatstone also devised the idea of electrically synchronizing clocks by connecting a number of these timepieces in different locations with one central clock in such a way that all would keep the same time. He improved the network of conductors first devised by Christie, and which we now call the Wheatstone's bridge, whereby an unknown electrical resistance can be balanced against one

that is known and thus its value can be determined, much as you weigh a pound of sugar by balancing its gravitational attraction against the earth's attraction for a definite piece of brass or iron which is called a pound weight.

All measurement is merely comparison by means of something familiar to us, as a foot, a second, a pound, a day. But we always have to start somewhere and say, "This is going to be our unit to measure with."

A man named James Prescott Joule, also an Englishman, was one of those who thought about the units by which things are measured. He was wealthy and the study of electricity early became an absorbing hobby for him. Before he was twenty he was able to prove mathematically that when two chemical elements were separated by electrolysis the amount of heat absorbed was equivalent to that originally produced during the combustion of the two elements when they combined. He wanted to find the "mechanical equivalent of heat," that is, how many units of mechanical energy are equal to one unit of heat. In dealing with money we would term this comparison the rate of exchange.

To do this he let a weight fall a certain distance and in falling it turned a paddle wheel in

a pail of water and this heated the water, just as you could heat up a pail of water by stirring it with a spoon, if you really had the time and inclination.

With great care the rise in temperature of the water was measured by Joule and the amount of water measured, allowance made for the pail and for the heat which escaped. The value of the weight and the distance it fell was easily measured, too. So mechanical energy could be compared to heat energy and, of course, by heating water electrically the effects of electricity could be compared with mechanical effects. To commemorate this great comparative work the name Joule is given to the electrical unit of work just as the names of Coulomb, Volta, Ampère and Ohm are given to the units of electrical quantity, force, current, and resistance, respectively.

But Joule was one of those who widened out the path until it embraced all branches of science. He evolved from his work the great laws of the Conservation of Energy which he gave to the world in 1847. In general these were his thoughts:

Energy, like matter, can neither be destroyed nor created. It merely changes its form and in any form it can be changed into energy of any

other form. When energy in any form seems to disappear, its exact equivalent in some other form takes its place.

But when energy undergoes transformation or is transferred from one body to another, the process is not completely reversible, some of the energy taking such form that it can't be recovered in reversing the process.

Finally, the total energy of the universe is a fixed and constant quantity.

These are magnificent thoughts, quite the grandest since Newton's laws, and while science is beginning to wonder a little about some of these things, Joule's theory has been of inestimable value. It is one of the three or four great landmarks in science. It tells us, for example, that the chemical energy of the coal we shovel into the boiler will reappear in the steam engine, minus some portions that remain in the ash, go up the chimney, or escape by radiation; and the mechanical energy of the steam engine will reappear in the electrical energy from the generator except for part which overcomes the bearing resistance, the air resistance and goes into heating the wires.

We are able to measure these different forms of energy, compare them, determine losses and make improvements so as to conserve part of

the loss, and we can calculate the efficiency of the various pieces of apparatus. It lets us know how much coal to arrange for, how big an engine to buy, when we are figuring on a certain output of electricity for a radio station. It enables us to calculate the amount of gasoline necessary for an airplane flight across the pole and the size of wire needed for a heating pad.

While to Joule belongs all the credit for this discovery, it was Herman Ludwig Ferdinand von Helmholtz, the distinguished German physician and surgeon, who established Joule's principles on a firm, mathematical basis. Helmholtz in 1847 asserted the identity of motion, light, heat, electrical, magnetic and chemical action, thus giving voice to one of Faraday's favorite thoughts. This was almost sacrilegious in the eyes of many scientists even at that time because electricity, magnetism and light were still regarded by all but a comparative few as subtle forms of matter. Even heat, in spite of the work of Count Rumford, was so thought of by many.

As late as December 16, 1880, after all the work of Faraday and Maxwell, in a lecture before the London Institution Sir Oliver Lodge stated, "What is electricity? We do not know. We cannot assert that it is a form of matter;

neither can we deny it. On the other hand, we cannot certainly assert that it is a form of energy; and *I should be disposed to deny it.*" Hence the announcement by Joule and Helmholtz *before* Maxwell's work that all these things were merely force or energy was discussed for quite a long time before being accepted generally and the discussion was not altogether calm and placid. In fact, it was a row!

Meanwhile the old thought of action at a distance was continually popping up. Men of old had looked up into the heavens and comprehended the orderly motion of the planets. Pythagoras, for example, nearly five centuries before the Christian era conceived of the planets as revolving around a central luminary and thought their velocities had the same proportion to each other as he had observed in the musical intervals. He knew these velocities were very great and so he believed they must cause a mighty rushing noise. But, as they were in exactly the harmonic ratios, he felt that the result must be sweet music excelling all earthly music, a tremendous chord, the famous "music of the spheres," which Pope refers to in his "Essay on Man."

"If Nature thundered in his opening ears
And stunned him with the music of the spheres,

How would he wish that Heaven had left him still
The whispering zephyr and the purling rill!"

Pythagoras, not knowing how else to explain that folks couldn't hear this wonderful strain, suggested that it was because they were used to it from birth and only its interruption would be observable!

This calls to mind that A. Porritt tells of a cage of Javanese birds which A. Conan Doyle once had. The birds when singing would go higher and higher with their notes. It was Doyle's greatest joy to rush visitors to the cage and have them signal by touching the table at the instant when they could no longer hear the note and he would do so himself. On one occasion Porritt records that fully twenty seconds elapsed after the sounds had become inaudible to him before Doyle signaled that he had lost them, and both could see that the birds were still singing. This led Doyle to remark his belief that all nature is full of unheard noises, an idea which Tyndall had previously recorded in one of his delightful essays.

But at the time of Pythagoras (500 B.C.), to continue our story, the only influence which was known to be capable of passing from one star to another was light. Newton added the con-

ception of gravitational action, a balanced attraction between these great masses which keeps each of them in its orbit like a stone whirled at the end of a string, but there is no string! How then did this force act? Now it is recognized that electric and magnetic attractions may cross interstellar space, but how? Men cannot conceive of action between two bodies without the bodies being connected by something. What is that something? Nothing has ever been detected but something must be there. To this something is given the name æther or, more commonly of late, ether.

Descartes, who has been mentioned before, invented the idea of an ether about 1644. In his system of philosophy, action at a distance must be through some intermediary plenum the matter of which is imperceptible to the senses but capable of transmitting light. The Cartesian idea really was that matter is characterized simply by extension; extension constitutes matter and matter constitutes space. There was a primitive elemental matter boundless in extent and infinitely divisible, out of which three forms of matter had originated, the dense, opaque matter of the earth, the luminous matter of the sun and the transparent matter of all space.

His discussion of these kinds of matter is

entrancing, an idea of it being gained by considering his insistence that the particles of transparent matter are spherical, and luminous matter comprises what has been scraped off the other particles when they were rounded! This transparent matter is whirling around, constantly straining away from the centers and tending to move outward but being closely packed it cannot move, yet the strain produces pressure and this transmitted pressure is light.

Our old friend Robert Hooke, the flying machine man, made some experimental observations which attacked this theory of Descartes that light is a tendency to motion rather than an actual motion. He allowed that there is "no luminous Body but has the parts of it in motion more or less" and that this motion is "exceeding quick." He showed that a diamond when rubbed in the dark will shine for some time but won't be wasted away, so whatever is in motion isn't lost. Hence the motion must be to-and-fro. The space of movement must be small, he observed, because the diamond as well as other luminous bodies is very hard and can't yield or bend. He compared the transmission of this motion through space to water waves or rings swelling out into circles about the point where a stone is dropped, and specifically refers to the

motion as undulating through a "Homogeneous medium."

Newton had a conception of the ether as capable of propagating vibrations in the same way as the air transmits sound waves, but faster, of course. This ether pervades all space, he thought, and the pores of bodies. To him it was not necessarily a single uniform substance but, as air contains vapor, so ether might contain "æthereal spirits" which would produce electricity, gravitation, and the phenomena of magnetism. As to light, he generously gave everybody his choice between corpuscles shot out from luminous bodies "or any other corporeal emanation or any impulse or motion of any other medium or æthereal spirit diffused through the main body of æther, or what else they can imagine proper for this purpose." He, perhaps, was the first to conceive of heat conductivity from a hot body to a cold one being accomplished by ether vibrations propagated between the two.

Nearly everyone at this time, including Newton, assumed that light was not actually the ether vibrations although they might exist in connection with it, but that light rays were streams of corpuscles emitted from luminous bodies, the corpuscles somehow exciting ether vibrations of dif-

ferent types depending on the colors. In any case the principle that light is essentially periodic in nature and different periodicities correspond to different colors, was set forth by Newton. He compared this theory of periodic vibrations in the elastic ether to sound waves and tones, in 1672.

In 1690 Huygens published at Leyden a greatly extended wave theory of light, which, together with his own experiments, seems to have had the effect of setting Newton more firmly than ever in favor of the corpuscular theory, although he never did commit himself definitely on this point. After his time it became customary to include light corpuscles among the chemical elements. Newton himself suspected that light corpuscles and matter might be transmuted into each other and Boscovich, a noted Jesuit mathematician and astronomer, some half century later had the notion that the "matter of light" was an element in the constitution of all bodies something as Franklin conceived this to be true of the "matter of common fire" and of "electrical fire."

In 1728 James Bradley at Oxford made astronomical observations with respect to the gradual propagation of light which lent support to the corpuscular theory, and the younger Ber-

noulli ten years later published a study of the ether which out-Cartesianed Descartes, yet narrowly missed hitting on exactly the transverse vibratory ether assumed a century and a half later by Maxwell. Franklin, interestingly enough, declared himself in favor of the wave theory, as did Euler, the great German mathematician of Franklin's time, whose partial blindness as a youth turned to total blindness in middle age. But it was the Quaker, Thomas Young, who really led the wavists to temporary victory, beginning in 1799, largely by his expounding of the phenomena of interference whereby he produced either colors or complete darkness by interfering light waves. So strongly was the corpuscular theory entrenched at that time that it is said that one of Young's pamphlets in reply to attacks on him sold only a single copy!

Laplace, Poisson and Biot took up the cudgels for the corpuscular men and with considerable success, aided by the important discoveries of a young Colonel of Engineers, one Etienne Louis Malus, who had served with Napoleon in Egypt. Colonel Malus happened to observe changes in reflected light corresponding to polarization and this gave heart to Young's opponents. Malus in 1810 won the prize of the French Academy for his discoveries but died al-

most immediately afterwards in his thirty-sixth year.

Strangely enough the man to rescue the wave theory from despair and establish it to the satisfaction of everyone was another engineer, this time a civil engineer engaged in Government work in Normandy, and he was also of Napoleonic contact, being one of those who enlisted in the attempt to bar the Emperor's return from Elba in 1815, and besides losing his job, he got arrested for his pains. Having nothing else to do, he studied diffraction during his enforced idleness and started on the exposition which brought him the prize of the Academy in 1818. His name was Augustin Fresnel and he, too, died a young man of thirty-nine in 1827 after having achieved such fame as comes to few.

Fresnel and Young between them in a series of marvelous deductions convinced even the most rabid corpuscular advocates of the error of their ways and built up a wave theory of light which still survives. More important to us they established the necessary sort of an ether for the propagation of waves.

It is pitiful to record that when in 1827 the Royal Society of England awarded Fresnel the Rumford medal and Young entrusted Arago

with the privilege of conveying it to Fresnel, the latter was found to be at death's door.

Science builds on hypotheses and it is a fundamental principle while supposing, to suppose exactly the sort of things that will meet every requirement. As new requirements are discovered it is only necessary to change the supposition. With the ether supposition of Young and Fresnel few have found fault. In general, their ether may be described as an elastic solid. Later it was somewhat liquefied, at least to a plastic nature, to meet certain requirements more easily associated with fluids. Later still the thought of elasticity of compression was revoked and the idea evolved that the elementary portions of ether resist absolute rotation about any axis.

The first objection suggested to the elastic solid was, how do the planets manage to plow through a solid at such enormous speeds without apparently encountering resistance? And the answer was given by Sir George Gabriel Stokes who was born the year after Fresnel won the prize and died in 1903 at the age of 84, after having made one of the greatest mistakes any man has ever made and but for which we probably never would have heard of Marconi.

Stokes called attention to such solids as wax

which, while rigid, are plastic enough to allow other bodies to pass through them easily. So he explained, if the ether had these qualities to an extreme degree, it could be rigid to such high speed vibrations as those of light while easily yielding to the much slower onward motion of the planets.

Joseph Boussinesq, a French physicist, born in 1842, thought up an especially good kind of elastic solid for the ether to be. Two groups were then debating whether the ether varied in elasticity in different bodies or varied in inertia but Boussinesq opposed both and assumed that it was the same everywhere in all substances and in interstellar space. He was probably the first to assume an identical, all-pervading, imponderable ether which was the sort of an ether Maxwell conceived as carrying the electromagnetic waves which are light, radiant heat and electricity.

Maxwell's conception was that magnetic energy is the kinetic energy or motional energy of this medium occupying all space and that electric energy is the energy of strain or distortion of the same medium. They always accompany each other. You can't have motion without strain nor varying strain without motion. You can't have electricity without magne-

tism nor changing magnetism without electricity.

Having determined that both light and electricity were different rates of vibration of the same medium, Maxwell wondered about the propagation of light in electrically conductive materials, that is, materials in which electricity could be propagated. Metals are opaque to light but best conduct electricity and Maxwell determined that the reason is that within the metal the energy of light vibrations is absorbed and converted into heat (Joulian conversion) in the same way as ordinary electric currents are absorbed and go to heat the wire.

From this we derive the notion that good conductors are necessarily opaque while good dielectrics are transparent—mica, glass, oil, water. Where they are not, it is usually the cause of some foreign coloring matter. Even ebonite or hard rubber is easily transparent to some wavelengths of light. There is also the law that the specific inductive capacity or dielectric constant of a substance (which determines its condenser action—see the chapter on Faraday) is proportional to the square of the refractive index with respect to certain long light waves. In other words, the electrical nature of any substance is bound up with its optical nature. Light and

electricity are different forms of the same phenomena, each being some kind of a periodic or regular disturbance in the all-pervading ether of space.

Long before there was any utilization of electric ether waves for radio, light waves were used to transmit signals and voice between isolated spots. Men talked to each other over beams of light just as now the artists of the broadcasting stations talk to us over those other ether waves that we have come to call radio and only recently there has been a survival of this old form of communication over beams of light.

We'll come to this a little later on.

PART III

COMMUNICATION

Three hundred years of progress and the final success of signalling by sound, voice and pictures sent over the wire in Europe and America long before the "elegant eighties."

CHAPTER X

A QUAKER MURDER BUILDS AN INDUSTRY

> "To the open ear it sings
> The early genesis of things."
>
> —Emerson

PROBABLY the first thought of communication at a distance with or without intervening connection, goes back to John Baptista Porta and his two compasses "having the alphabet writ about them," as told in Chapter II. A modification of this method was suggested but nowhere have I found a record of anyone trying it out.

The idea was to mutually transplant the skin and perhaps the flesh from corresponding portions of two persons, as the arms, the legs, or the breasts, and it was said these parts would retain such sympathy with their original bodies that any injury done to either transplanted piece would be felt by the first owner. Either of the persons involved could, by pricking the transplanted flesh on himself "with a magnetic

needle" communicate a corresponding twinge to the other. In that way messages could pass between them by any prearranged code. This would seem an easy thing to try now with all the skin grafting and gland transference going on.

Of course, it was not until after the work of Dufay that wires were available for carrying signals. We might consider the ring of 200 soldiers shocked by Abbé Nollet as an early instance of signal transmission or, if that ring seems too small, take a more noted instance, not heretofore related in this book, where the same experimenter in the same way under orders from Louis XV sent a Leyden jar discharge through some nine hundred Carthusian monks, each connected to his fellows by a length of iron wire and all forming a circle more than a mile in circumference. As in the case of the soldiers, the monks gave visual evidence that the signal had reached them!

These Nollet experiments had no real relationship to the transmission of intelligence or message sending, although they do emphasize the fact that the closed electric circuit was known as soon as news of the Leyden experiments became widespread.

The suggestion of a telegraph system fol-

lowed very shortly in an anonymous letter published in the *Scots Magazine* at Edinburgh on Fed. 17, 1753, just after Franklin's kite experiment in America. Only the initials "C. M." are signed by the writer who seems to have feared being looked upon by his neighbors and friends as a questionable character, perhaps a magician or perhaps just plain crazy, as many are considered even now, who write their ideas to newspapers.

This fruitful suggestion preceded Morse's invention by eighty years and gave rise to eighty years of experimentation by many men before his particular form of telegraph system was adopted. In view of events many years later in connection with the discovery of the telephone and of wireless, it is of great interest to us to study how Morse's device was an improvement on what went before and why in America alone school children are taught that Morse invented the telegraph.

There is no more striking example of how futile it is to give sole credit to any one man for any invention. Almost always he is but one of a tremendous line of workers all of whom did their bit. We forget those who blazed the path into the unknown and confuse the man who devised the "best" with the one who first had the

inspiration without which the later man might never even have thought of the problem. It is much like crediting the building to the man who sweeps it and makes it habitable.

"C. M.'s" suggestion was that a wire for each letter of the alphabet should be stretched on insulators between the two points of communication and at each end of each wire a metal ball should be suspended, having under it and close enough for the ball when charged to attract it, a small bit of paper with the required letter printed on it. At the sending station the electric machine could be placed in successive contacts with the proper balls to spell out the message and at the receiving station one might read the message by noting the order of attraction of the papers, This, of course, was thoroughly practical but involved much wiring.

In 1774 Lesage of Geneva devised another sort of system of no particular consequence but 13 years afterward Lomond, a Frenchman, proposed to use only one wire instead of twenty-six and to use a suspended pith ball indicator instead of the papers, various predetermined movements of the light pith ball as it is charged representing the necessary letters in some sort of code.

In 1790 Chappé, who later invented the

semaphore, used to this day in railroad signaling, devised a telegraph in which two synchronized clocks were the indicators, one at the sending station and one at the receiving point. The same letters and figures were written about each dial and the character pointed to by the second hand was to be read at the instant an alarm was sounded.

At first Chappé used for his alarm a stew pan struck with a stick by hand at the sending station. Of course, the receiving end had to be near enough for the reader there to hear the resulting bang through an open window. Chappé soon found that sound didn't travel fast enough for the observer to hear the pan struck at the right instant to look at the clock so he tried to develop a signal operated over a wire by the Leyden jar. However, at distances great enough to do any more than shout, he couldn't insulate the lines well enough to suit him so he threw the whole business up in disgust, and got up the visual device known as the semaphore, thus achieving everlasting life.

In 1795 Cavallo in London transmitted sparks from Leyden jars through wire "according to a settled plan," and in the same year Francisco Salva suggested to the Spanish Academy at Barcelona the idea of going back

from a single wire to six or eight, not separate, but rolled together into a single cable, each wire being amply insulated. He used pitch-coated paper to insulate each conductor and wound paper about the whole cable, curiously anticipating the formation of present-day telephone cables in this first cable ever made.

Salva suggested also, that instead of suspending this cable in the air on poles, it should be laid in tubes underground, preserved from moisture by resin coatings if need be. He pointed out that even the sea need not interfere with connecting up two places, for his cable could be made waterproof and just laid along the sea bottom for the distance that was required. Salva did quite a little experimenting along these lines but never used less than about 17 double wires, one pair for each letter he deemed essential in the alphabet. In place of picking up paper with letters on them, Salva's receiver was a number of tin foil letters on glass, arranged so each letter had a spark gap. Then, as the Leyden jar communicated its charge along the wire from the sender, the indicated letter would be illuminated by a flash across the spark gap.

All kinds of devices were suggested following these ideas. Sir Francis Ronalds, not then knighted, suggested a single-wire system, not so

greatly different in nature from that of Chappé but developed into a very workable system between 1816 and 1823. He insulated his conducting wire by glass tubes and then laid it in a wooden trough, pitched within and without and sealed with wax. Two clockworks were synchronized and each rotated a clock face disc with a slot in it large enough to see a letter through. Below was a stationary disc with all the letters and figures on it so that in a complete revolution of the clock face disc, each letter would show through the slot. A pair of pith balls suspended from the conducting wire would repel each other and attract attention whenever a current passed through the wire. Hence, both sender and receiver would see the same letter at the same time and either could instantaneously attract the other's attention to the revealed letter by the motion of the pith balls, and thus spell out a message.

To shorten the process Ronalds invented a code so that words and sentences could be sent by two or three signals. In order that the apparatus need not be observed continually a "Volta cannon" (a tube containing an explosive mixture of hydrogen and oxygen set off by a spark) was provided to attract attention to the beginning of a message. Ronalds urged that

telegraph stations be established all through the British Isles. He proposed two underground tubes taking different routes to the same place, the better to prevent mischievous interference from rogues and "should they still succeed in breaking the communication—hang them if you can catch them, damn them if you cannot, and mend it immediately in both cases."

Ronalds pointed out that over long distances, troubles would be experienced from the condenser action of cables and the retention of the charge, just as was found to be the case when the cable was first laid down under the Atlantic, a condition remedied by Sir William Thomson (Lord Kelvin).

Ronalds built several lines both underground and overhead, one of the latter being over eight miles long.

All of the schemes so far had been based on frictional electricity but Galvani's experiments were well known and in 1800 the same Francisco Salva mentioned before built a line a quarter of a mile long using as an indicator the convulsions produced in frogs' legs. He found that without the frictional machine there were signals at one station because of the electricity generated at the other by the metal in contact with the frogs' legs, the first indication of the possibility

of using voltaic electricity for signaling purposes.

Later he applied the Volta pile to the wire instead of a frictional machine and at the receiving end, instead of frogs' legs, he put the two ends in acidulated water and used the bubbling due to decomposition of the water by the electric current, as his signal indicator. Sömmering in Germany used this same arrangement in 1809, except that he had a wire for each letter or figure and each wire had a gold terminal adjacent the corresponding letter marked on the trough containing the water. Then the letter desired was indicated by bubbling of the liberated gas from the near-by terminal.

To attract attention at the start, gas liberated at a terminal under an inverted cup would raise the cup, operate a lever and set off an alarm—just such a combination as Rube Goldberg in these later years has made familiar to millions. Even more worthy of the cartoonist's skill was the proposal of one Jules Alix who, reading that garden snails pull in their horns when electrified, proposed setting them up on the incoming wires and reading messages by watching them put their horns in and out.

When Oersted finally discovered the turning of a compass needle by a current, Laplace saw in

this an ideal indicator for telegraphy. Ampère in 1820 suggested replacing the bubbling terminals in such devices as Sömmering's with little magnet needles under the wires. Nine years later Professor Fechner of Leipsic suggested using the galvanometer as the indicator and in 1830 Ritchie of London did this on a large scale, using twenty-six circuits and twenty-six galvanometers, one for each letter. Right afterwards Baron Schilling, an attaché of the Russian Embassy at Munich, devised a system with a single circuit comprising a direct and return wire. The sending device was a key which made or broke the circuit or reversed the direction of the current through the line at will.

The receiver was a galvanometer. Under the needle and fastened to it was placed a white paper disc painted black on one side so that either the white or the black face could be brought into view as the current was made to flow one way or the other. Using W for white and B for black, a code was made up for the letters of the alphabet almost identical with the code used by Morse a few years afterwards using "dot" and "dash" instead of B and W. This Schilling system was used abroad by railroads for several years prior to Morse's inven-

tion of his well-known electromagnetic type of receiving equipment.

Gauss and Weber, the Siamese twins of science, at Göttingen, devised a somewhat similar arrangement to that of Schilling, but used a mirror on the galvanometer needle with deflections left and right, which made possible the use of a bi-signal code with L and R as the elements, instead of B and W. Steinheil took up their work in 1835 and used a magneto-electric generator for his source of power instead of the Volta battery. He devised a receiver comprising a magnet and an armature attracted by it. The armature carried an inking device so that a signal resulted in printing a dot on a strip of paper carried along by clockwork.

In another type of indicator the magnet armature struck gongs of different tones, which went to make up another style of bi-signal code. Steinheil thus at one stroke became the first inventor of the printing telegraph or "stock ticker" and of a style of sounder, the latter being the first device that was not visual in operation.

In the year 1838, six years after Morse first began experimenting, Steinheil at Gauss's suggestion tried to use the two tracks of a railway

line as conductors to provide both outgoing and return circuits but found it too difficult to insulate them from the ground. He was so impressed by the conductive power of the earth that he was tempted to try it as his return conductor in a complete telegraph circuit, the other side of the line being an overhead wire. It worked perfectly and, of course, cut the cost of installation by a considerable amount. It was an immensely important step in telegraphy.

Steinheil was thus the first to do away with one wire. Hertz, of course, did away with the other so, in that sense, Steinheil became a forerunner of wireless. Even in a more definite way radio appears to date from Steinheil because he seems to have recognized that it might be possible to do away with any metallic conductor whatever. He said, "Had we means that could stand in the same relation to electricity that the eye stands to light, nothing would prevent our telegraphing through the earth without conducting wires; but it is not probable we shall ever attain this end." And we didn't until Hertz in his resonator gave us an electric eye.

Although Steinheil was the first to use the earth return for the transmission of intelligence, it had been discovered long before his time. A Frenchman named LeMonnier had used the

pond in the Tuileries Gardens as one portion of a conducting line and William Watson in England, knowing about this experiment, contemplated transmitting the "commotion" of a Leyden jar across the Thames. In 1747 he performed this experiment. His line was stretched 1,200 feet along the Westminster Bridge with the two ends dipping in the water to complete the circuit.

This worked so well that he desired a longer stretch and chose the New River at Stoke-Newington, this time stretching the line along the river bank, the return being through the water. Accidentally he found that with one end in the water and the other end touching the ground, there was as good a circuit as with both ends in the drink. This led him to try both ends of the return sunk in the ground and he very successfully carried the discharge through a distance of four miles in that way. Watson is therefore the discoverer of the earth return first applied to the telegraph by Steinheil.

After Steinheil Mr. Edward Davy (not Sir Humphry) suggested a form of "relay" or "electrical renewer" whereby a long line may be broken up into shorter stretches, the relay of the first circuit closing the second circuit through local batteries and so on to as many circuits as

desired (like the runners in a relay race), thereby avoiding the need of high voltages or large currents where long distances are involved, the objection to these being the difficulty in insulating the wire. This was not overcome entirely until Goodyear by accident invented his process of vulcanizing rubber in 1839 and soon afterwards made it available for wire covering.

Edward Davy also invented a chemical recorder or printing telegraph in which ink is not required, the recording strips of calico being chemically prepared so that contact with the metal finger of the receiving mechanism would make a dark mark.

Next came the Wheatstone and Cooke team in 1834, as mentioned in a previous chapter, with an arrangement not so good as Steinheil's but also adopted in England for railroad use and afterwards improved. It is this system which really was responsible for the sudden growth of interest in the use of the telegraph and its final success abroad, at least.

Up to that time it had no general use, being adopted only by a few railroads. People wouldn't put any money in it as a general communication plan. But about 1840 a Quaker committed a murder in an outlying part of

England and rushed to the railroad station where he boarded a train for London. News of the murder reached the station shortly after the departure of the train.

Regrets being expressed that the guilty party had so easily escaped, some one had the bright idea of sending word ahead of the train by means of the railroad telegraph. The operator was persuaded to try it. He seems to have got the London operator quickly enough, but wasted much time spelling over and over to him the word "Kuaker" (there was no code for "q") with which word the message started, the Londoner apparently trying to figure out what part of the railroad system that was. Finally, the first bystander suggested sending the whole message, which was done, and the Londoner immediately saw what was meant by "Kuaker."

Although all this took considerable time, the man was apprehended as he stepped off the train and all England rang with the feat. The incident enabled a few capitalists to visualize the possibilities of speed in communication and sufficient funds were quickly raised to promote an adequate telegraph system in England about the same time as Morse was struggling with the Congress for his Washington to Baltimore experiment.

In America patents on telegraphs were granted to J. Grout, Jr., in 1800 and to W. Schultz of Baltimore in 1809. As early as 1831 Joseph Henry had devised several forms of electromagnetic signal devices. Morse's apparatus of 1837 was a commercially practical arrangement of one of Henry's instruments.

Morse, a product of Poughkeepsie, was himself an artist. He appears to have first thought of doing something with the telegraph in 1832 on his way back from one of his long sojourns in Europe. One of his fellow passengers was a Dr. Jackson of Boston who was familiar with the various attempts being made in Europe and besides was somewhat versed in electricity and chemistry. Jackson, in fact, had with him one of Ampère's electromagnets and his demonstration of it to Morse seems to have been the spark which started Morse's genius burning.

Morse's first apparatus in association with Jackson was a chemical recording device, the passage of the current on contact through the impregnated paper tape causing discoloration. Later he made a printing telegraph, but the operators seem to have found it as easy to read the instrument by its sound as by looking at the tape, so Morse and his associates turned to the

electromagnetic arrangement mentioned above, but not the small devices that we have under his name to-day. His first magnets used on the Baltimore line weighed 185 pounds, the arms being 18 inches in diameter and wound with wire about the size of the lead in a lead pencil. The magnets Morse made himself were inadequate and it was Joseph Henry who taught him how they should be wound.

The great advantages of the Morse system as it was gradually developed are that the so-called dot and dash give a bi-signal code which requires no reversal of the current and the two elements are easily distinguished by their sound without visual attention. They become to the experienced man almost a form of language and lend themselves readily to fast sending and receiving. It attracts immediate attention and requires no preliminary alarm.

This was the end of the search for a fundamental system although at the present time needle and reflection galvanometers are still in use in some places abroad. One of the objections to the dot-dash system in signaling was humorously stated by Sir William Preece in the late eighties. Preece pointed out the ease with which errors could creep in, a lightning flash in America causing an extra dot in England mak-

ing the word "mine" into "wine"; an earthquake in Japan adding a dash to turn "life" into "wife"; or a wild goose striking one wire and contacting with another being sufficient to change "good sight" into "good night."

In 1850 John Mirand invented the common form of vibrating electric bell, giving us the "makings" of the most used short telegraph line in the world, the one that tells us somebody is at the door but makes no distinction between a postman bringing us a message of good cheer or a bill-collector aiming to deprive us of hard earned cash.

Gintl in 1853 and Stearns of Boston seventeen years later suggested duplex methods whereby signals could be sent simultaneously in opposite directions, a simple arrangement of the local circuits on each end of the line. Stark of Vienna and Bosscha of Leyden in 1855 invented diplex methods whereby two messages could be sent at the same time in any one direction. This is more complicated but is done by polarizing the magnets so that they will operate only when the current flows in one certain direction through them. Then other magnets are wound so they respond to current flowing in the other direction. One key is a reversing key and the other is not, so each key operates only one

set of the magnets but both can be worked at the same time, by two independent operators. Something of the same kind was afterwards used in selective ringing of telephone bells on party lines.

Heaviside of London in 1873 and Edison in Newark a year later devised the quadruplex system, combining duplex and diplex methods so two messages in each direction could be sent at once, four all together on the wires. Delany expanded this to "multiplex" telegraphy. Later Wheatstone conceived the automatic high speed transmitter, punching the message in a tape and then running the tape at high speed through the transmitting machine. Cowper in 1876, J. H. Robertson later, and Elisha Gray in 1893, all brought out autographic or writing telegraphs similar to those frequently seen in railroad stations for announcing train arrivals.

All this was before Dolbear, Hughes, Marconi or Hertz, except for Gray's invention last mentioned. It is part of the background of these outstanding figures.

CHAPTER XI

FROM BEER BARREL BUNG TO VIOLIN

"Untwisting all the chains that tie
The hidden soul of harmony."
—MILTON, "L'Allegro"

EXCEPT in an incidental way and in the last chapter we have not been concerned with those men who merely invented pieces of apparatus, unless the apparatus grew out of the new and important discoveries in the rise of electrical science. Such, for example, were Peregrinus with a pivoted compass pointing the way to the poles; Gilbert with an electroscope, which now is used to indicate the presence of radium; Guericke with his electrical machine; Dufay with the conductor wire; Musschenbroek with the Leyden jar; Volta and his battery; Ampère and the galvanometer; Faraday with his induction coil, transformer, motor and electric generator; and so we might go on. Yet more than two hundred men of importance have walked through these pages up to the present point. These men have advanced

thought and theory, flung high the flaming torch of science and left the world a little richer in philosophy and experiment.

Some have taken but a step, sometimes blind to what it meant. Others have carried heavy loads up seemingly impossible mountain slopes into the full light of the sun. Many of those seemingly least fitted by training have best survived the fierce white light that has beat around them in the ages since they lived. We have had Gilbert, a physician; Guericke, the burgomaster; Dufay, retired from the army to superintend a park; Franklin, a printer; Priestley, a clergyman; Galvani, an anatomist; Fresnel, an army engineer; Faraday, a chemist; Helmholtz, a surgeon; and Hertz, a civil engineer. But the great generalities have always come from training, as witness Descartes, Newton, Joule, and Maxwell, all preëminent mathematicians even before their great laws and hypotheses were accepted. Thus was the scientific world.

In commercial matters some similar mixture of men was the usual thing. The progress of telegraphy was carried out by casual citizen observers, professional men, scientists, and Samuel F. B. Morse, the artist. It was rather a ragged progress. Telephony grew up in the same way but, unlike Morse, Bell was among

the first workers in the field so far as reproduction of the human voice is concerned.

For centuries it had been known that articulate sounds could be reproduced by the use of two thin diaphragms made of membrane or of metal and connected together at their center points with a tightly drawn cord or wire. Faraday had long before investigated the currents set up in a magnet coil by the movement of a diaphragm in front of the magnet, but it was a casual experiment, although he had sent such currents through the windings of another electromagnet.

In 1837 an American physicist named Page had found that when a bar of iron is magnetized there is a sharp, audible click, and he gave it the name of "galvanic music." Joule in 1842 discovered the elongation of iron under magnetic strain and De la Rive the next year stated that the clicking noticed by Page was a sound due to the elongation discovered by Joule, which elongation now is believed due to a realignment of the iron molecules, as shown by the work of Weber and of Ewing.

In 1860 a German schoolmaster, Philip Reis of Friedrichsdorf, to utilize this clicking property devised a vibrating membrane carrying a contact which made and broke an electric cir-

cuit to a small magnet wound with wire, as the membrane was vibrated by any sound wave in its vicinity. Suitably enough, the membrane was a sausage skin and it was stretched over a hollowed-out beer barrel bung in which the contacts were inclosed. The magnet on which the wire was wound was a simple sewing needle stuck in the bridge of a violin.

As a note was sounded in front of the sausage skin, its vibration would be as rapid as that of the surrounding air. The make and break contact would be as rapidly actuated and thus the current to the coil around the needle would rapidly magnetize and demagnetize the needle, causing a succession of clicks of the same rapidity as the membrane vibration. These would be communicated to the violin which would act like a sounding board. In other words, the violin would reproduce the note sounded before the membrane.

It was a musical telegraph, reproducing musical sounds. Some speech was reproduced with it, such as a single syllable or a short word but the reproduction was indistinct. Reis made many other transmitters but in none of them was speech reproduced well because he broke the contact as the diaphragm vibrated instead of merely varying the pressure between the con-

tacts. On the other hand, if he hadn't broken the circuit, he wouldn't have reproduced the clicks, so all in all the best that can be said is that he first transmitted sound.

Strangely enough Bell's first work, which began about 1864, was on musical telegraphs,—steel harps arranged like the sounding board of a piano, sort of harmonic note affairs. They didn't reproduce voice either and for the same reason that Reis' devices didn't. The contacts were made and broken. In 1875, however, one of the things stuck and merely varied the contact, so that purely by accident he and his assistant devised the forerunner of the present speaking phone. Bell showed great acumen in taking advantage of this gift from the gods.

At the same time Elisha Gray made a speaking phone in which the transmitter was a platinum wire dipping into water arranged so that the diaphragm vibration would vary the amount of dip and thus change the water resistance and the electric current. A most remarkable thing is that Gray of Chicago and Bell of Boston both filed patent applications in the United States which reached the patent office in Washington on exactly the same day, almost at the same moment, and neither knew of the other's existence.

Changes and improvements followed imme-

diately as Bell's device, although showing a correct principle, was inoperative from a practical standpoint, and Gray with his backers were finally defeated in the law courts, which means nothing whatever in judging their respective contributions to science. A man may well be awarded priority legally because of technicalities, rules of practice and legal precedent, or even public acquiescence (which merely means public ignorance), or because to do otherwise would cause established enterprise enormous loss of capital, or for a thousand and one other reasons, but priority scientifically and historically is awarded on the sole basis of who got there first, a quaint idea!

Varley and Dolbear, the latter a Professor at Tuft's College and an early claimant as the original inventor of a voice telephone, both designed receivers in which the electric attraction between opposite plates of a condenser was used instead of the electromagnetic attraction of a coil and an armature. To-day that sort of thing has been in use for condenser microphones at broadcasting stations.

In 1866 Du Moncel had discovered that pressure between two conductors diminished the contact resistance and a transmitter was later made up by Edison involving this principle, the voice

varying the pressure of a diaphragm against a carbon button. Hughes in 1878 devised a far more sensitive arrangement having loose contact between two conductors and gave it the name it still bears, the "microphone." The Blake transmitter is of this type. An English clergyman named Hunnings suggested the use of carbon granules packed loosely in a confined space, thus making a multitude of microphonic contacts. This is the transmitter "button" used in many present-day telephone instruments, in broadcasting "mikes," in dictaphones, and similar devices.

To Bell indirectly we also owe the phonograph as a by-product of the telephone. First, because it was in an attempt to make a loud-speaking telephone that Edison hit on the original idea, the needle in a vibrating telephone diaphragm accidentally pricking his finger and inspiring the thought that it would make indentations something like a printing telegraph; second, because after Edison had produced a crude talking toy, he made a great many unsuccessful attempts to remedy its defects but gave it up as he could see nothing in it for the reasons he himself stated in the *N. Y. World,* November 6, 1887. Mr. Edison then said: "It weighed one hundred pounds; it cost a mint of money to

make; no one but an expert could get anything intelligible back from it; the record made by the little steel point upon a sheet of tin foil lasted only a few times after it had been put through the phonograph. I myself doubted whether I should ever see a perfect phonograph ready to record any kind of ordinary speech, and to give it out again intelligibly."

Bell got the Volta prize of 50,000 francs from the French government for his invention of the telephone and with this money in 1881 formed a partnership with Dr. Chichester Bell and Charles S. Taintor to develop the phonograph into a practical thing. They first invented the wax record and then the continuous groove cut in the wax instead of the separate indentations in tin foil used by Edison. They made the needle the laterally moving part instead of holding the needle still and moving the record along as well as rotating it. They also saw the necessity for absolutely constant speed and added the governor. In fact, everything worth while except the original conception of reproducing speech mechanically, was discovered or invented by this group, who were to do much more than this toward sound transmission and, in fact, one or the other of them helped lay much of the groundwork of radio.

If credit is given to Morse for the telegraph, to Bell for the telephone, to Edison for the incandescent light, to Marconi for the wireless, on the same grounds Taintor is the inventor of the phonograph. If to the originator goes the credit, all of these men lose out in favor, respectively, of "C. M.," Reis, Lindsay, and Loomis.

Before Graham Bell invented his telephone, J. E. May (or Mayhew) discovered the peculiar electrical properties of the metal selenium. This was in 1873. He was an assistant in the laboratory of Willoughby-Smith and his discovery, like pretty nearly all the important ones we have mentioned, was purely accidental. He noticed that the selenium conducted better in one case when it happened to be light than in another instance when it was dark. This led to an investigation and it was soon found that varying the intensity of the light which fell on the metal, varied the conductivity of it. The same property to a less degree is now known to be possessed by tellurium and by carbon. It is probable also that either silicon, phosphorus, or sulphur will be found to have a similar action.

An amazing similar effect is that the resistance of a thin plate of metal, bismuth and tellurium being most effective, virtually changes with the strength of a magnetic field which

strikes it, the bismuth increase being so great as to afford a means of measuring the strength of the field. This is the "Hall effect" discovered in 1879 by E. H. Hall at Baltimore repeating an experiment suggested by H. A. Rowland. Thus it is apparent that the relation of bismuth to magnetism is the same as that of selenium to those magnetic waves we call light. It should therefore be of some usefulness in picking up electromagnetic disturbances. (Since writing this the author has seen in the *N. Y. Times* of Jan. 7, 1927, that Dr. P. H. Craig, after a study of the effect at the University of Cincinnati, has patented a use of this principle applied to rectifiers. The news item refers to Hall and Des Coudres as responsible for the principle. S. P. Thompson and Righi really found this particular variant.)

In 1878 Graham Bell and Taintor used selenium in the production of what was called the photophone. This was only three years after Bell's invention of the telephone. In the original photophone, of which these experimenters suggested over fifty modifications, the sun's rays were reflected by a mirror to a silvered glass or mica diaphragm placed over a mouthpiece. From the diaphragm at rest the light was reflected to a receiving mirror of parabolic shape

which focused the rays on a selenium cell connected in an electrical circuit with a telephone receiver. When the mouthpiece was spoken into, the polished diaphragm would bend in and out, changing its shape as it vibrated, becoming alternately convex and concave or partially so. This made the light reflected from it more or less divergent, thus varying the intensity of the beam which reached the parabolic mirror and in the same degree varying the electrical resistance of the selenium on which the changing light was focused. Thus was created a sound in the headphones corresponding to the words spoken into the mouthpiece. By 1880 the photophone and similar devices would transmit voice clearly two or three hundred yards and it could easily have been recorded on a modern phonograph record.

Experiments were made with colored lights and with the invisible waves beyond the spectrum, all of which were more or less successful. Many years afterwards, in 1898, Prof. K. Zickler suggested a peculiar modification of the idea. His was a telegraph. Knowing, from Hertz's researches, that a spark leaps much farther in a gap where there are ultraviolet rays, he proposed that the receiver should be a spark gap, energized but of a greater length than the potential would jump. Then from the sending

station a beam of ultraviolet rays is directed toward this gap, causing the spark to jump. The regulation of the beam, and through that the spark, could be utilized for signaling.

Later in the eighties, the arc light was used as a source instead of the sun and a multitude of inventors worked on this early form of wireless. Not only was the light falling on selenium used as the active medium but also receivers were built where the heat rays of the light beam focused by similar parabolic mirrors on a small blackened or charred piece of cork, made such alterations in the volume of the cork as to produce sound waves in the surrounding air. Such a device is called the thermophone and was exhibited by Bell at the Chicago World's Fair in 1893. It had been described as a possibility by Steinheil as early as March, 1839, as a method of telegraphy.

Various modifications of light telephony covering distances of several miles and finally resulting in two-way conversations over a light beam, followed the discovery in 1898 by Simon of the speaking arc, rather strangely foreseen back in November, 1880, by a writer in the journal *Engineering*. By 1901 talking films were made, the instrument being called the photographic phonograph or photographophone by

the discoverer, Mr. Ernst Ruhmer. It is of interest now as being almost identical with what is used in some talking movies. That was a quarter of a century ago.

As for the transmitting of pictures over wires, away back in 1856 Caselli sent designs by telegraph, using for the transmitter a cylinder covered with tin foil on which the designs were drawn in insulating compound. A contact pin traveled over the revolving cylinder much as the needle does on the cylindrical record talking machines. The circuit was made and broken as the lines passed under the contact pin and, on the receiving end, by electrochemical action, a synchronized cylinder and its mechanism reproduced the designs directly.

When the effects of light on the electrical resistance of selenium became known in 1873, various schemes to substitute selenium for Caselli's tin foil were proposed, those of Senlecq in 1878 and Perosino in the following year being most worthy of study. Senlecq's plan with variations was put into use by Korn in 1904, who transmitted photographs several hundred miles, the scheme in general being the same as that used of recent years by newspapers in transmitting photographs over the wire. The negative was wound on a glass cylinder and a

narrow beam of light used as a stylus passing through the film and by reflection to a single selenium cell. The resistance of the cell varied according to the shadow of the negative. At the receiving end the current was passed through an evacuated tube which grew brighter or darker as the current changed. These variations in light were focused on another cylinder covered with sensitized paper, which reproduced the original negative.

In 1907 Korn made photographic transmission from Paris to London by a slightly different arrangement, the result having the characteristic line effect of recent photographs.

A very different method in which selenium is not used has been developed by Edouard Belin, although originally produced by Mr. Swinton. He found that bichromated gelatine becomes insoluble under strong light, so under the negative he exposes a film of this gelatine and wets it, whereupon the portions of the gelatine exposed to light swell up more or less in proportion to their intensity of exposure, while protected parts remain flat. This is then a sort of relief map of the negative and is wound on a cylinder over which a stylus traces its path. A microphone is attached to the stylus and its electrical resistance is, of course, varied by the rising and falling

stylus, the intensity of the current transmitted thereby varying. At the receiving end an oscillograph has its mirror deflected in proportion to the current and a light beam is reflected thereby to another cylinder on which is a sensitized film to receive the result.

So far the required synchronizing of the cylinders has not been achieved by any radio method and until that is done the result of these schemes applied to radio transmission of still pictures will not be very satisfactory. The transmission of moving pictures of any size more than a few feet under present conditions and with any apparatus now in sight is mathematically impossible. It will be some years before this is done commercially. Meanwhile a commercial use of radio transmission has appeared in the sending of weather maps by radio to ships at sea by C. F. Jenkins in coöperation with the Weather Bureau. The printed map is placed in the receiver which draws dots and lines corresponding to the weather details.

It would be unjust to leave the history of the telephone without recording that in 1924 in Florence, Italy, according to contemporary newspaper accounts, there was unveiled a marble tablet placed on the Public Post and Telephone Office with a medallion portrait of a Florentine

citizen, Antonio Meucci, "the inventor of the telephone—poor and defrauded of his rights."

Meucci, it seems, was born in Florence in 1808 and as a young man became a political refugee and settled on Staten Island, N. Y. He made pianos and candles. His home became a refuge for radicals and to them in 1849 came Garibaldi. The great Italian patriot labored for a time in Meucci's candle factory and there he and Meucci secretly experimented with a primitive sort of telephone which is said to have been long afterwards presented to the president of the N. Y. District Telephone Co. In 1871 Meucci is said to have applied for a patent on his invention but through bad legal advice it seems never to have seen the light of day. He died in 1889.

That Garibaldi came to Staten Island for a time about 1849 is a fact. I have not been able to verify any of the rest of the story except that no patent to Meucci was granted in 1871 or the years immediately following.

It might also be mentioned here that selenium is no longer used in light telephony, nor in television experiments. Mr. Theodore Nakken of Holland has invented and patented the photoelectric tube which is so much quicker in its response and so much easier to operate that it is universally used in all work connected with

light. This tube is the cause of the greater success of late years in sending pictures over great distances. It is a simple radio three element tube having within and connected to the grid, a mass of caesium, rubidium or other metal of the alkali group which metal has the peculiar property, long known to physicists, of giving off electrons and thus changing its own potential, when exposed to light. As the intensity of the light varies, the potential of the mass varies and that variation is instantly communicated to the grid of the tube. The grid voltage variation thus varies the plate current of the tube in the usual way.

PART IV

SOUNDS IN SPACE

A short story of the growth of radio from the time of the Civil War through Dolbear, Hughes, Preece, Marconi and others to the work of Fleming and De-Forest and the beginning of broadcasting, with a tribute to all the wireless operators, and an index.

CHAPTER XII

WHO KILLED COCK ROBIN?

"Magnetic beam, that gently warms
The universe and to each inward part,
With gentle penetration, though unseen
Shoots invisible virtue ev'n to the deep."
—MILTON, "Paradise Lost," Book III.

I

BEGINNING with the early experiments of earth conduction, and water conduction, the idea arose of telegraphy without metallic connection between stations but never until the proposal of Mahlon Loomis about 1866 was there any attempt to transmit through space above the earth, nor any mention of such an idea except as suggested through the two harmonized compasses of Porta, previously discussed, and there, of course, no mention was made of how transmission took place.

Loomis has been variously characterized as a colossal faker, a dreamer, a remarkable character or all three. He was certainly not a faker nor an idle dreamer. He really accomplished some-

thing. Aware of the fact that the atmosphere is always more or less charged with electricity he knew that the higher the level, the greater the increase of potential. He conceived of the idea that the very lofty charged stratum was more or less independent of the disturbances which affect the strata nearer the earth's surface and would be in a substantially constant electrical condition so that any electrical upset in that stratum at one point could be instantly observed at any other point in the same stratum throughout the world. At least this seems to have been his thought and it is within the realms of possibility even as he stated it.

In his patent No. 129,971 dated July 30, 1872 this paragraph occurs:

> As it was found possible to dispense with the double wire (which was first used in telegraphy) making use of but one, and substituting the earth instead of a wire to form the return half of the circuit; so I now dispense with both wires, using the earth as one half the circuit and the continuous electrical element far above the earth's surface for the other half. I also dispense with all artificial batteries, but use the free electricity of the atmosphere, coöperating with that of

the earth, to supply the current for telegraphing and for other useful purposes, such as light, heat and motive power."

We might now, with the knowledge gained in the intervening half century, change the language, but we must recognize his foresight, because this was written before power transmission, before the incandescent light and before electricity was accepted as a form of energy.

To reach the upper strata he used kites carrying large squares of copper wire gauze, held by strings in which fine copper wires were enclosed, thus insulating the wire in its passage through the lower strata. These were the first aerials to be devised, the first condenser plates to be elevated above the ground. That honor is, at least, due Loomis especially as after his work but never before it, kite and similar aerials were frequently called into the service of inventors of communication systems and the elevated aerial devised by Loomis is the very basis of all radio. He also used a ground connection.

To test the idea he chose high mountains in West Virginia eighteen miles apart. From each peak kite-supported aerials were sent up. In the sending aerial he made and broke the connection through the coil of a galvanometer from

kite aerial to a buried coil in the ground. On the receiving mountain his aerial-to-ground path was through a galvanometer connected in the circuit. Believe it or not, in the presence of prominent men he sent messages both ways between the two stations for a continuous period of three hours on one occasion in 1866, the first signal transmission through space. He also communicated between two ships "at sea on Chesapeake Bay—two miles apart."

Loomis was a dentist in Washington, D. C., and, from his diary and notes, we learn that he began work on this scheme about 1865. His first success was on the occasion mentioned, the mountains having an elevation, he says, of about 2000 feet and his kite wires having been each 600 feet long. His "ground" was a coil of wire "laid in a wet place." (On another occasion his sketch shows plates in the ocean, in connection with a scheme to signal with Japan.)

The signal method consisted of "three deliberate ½ minute connections" made with the kite wire to the galvanometer already connected to ground, repeated at a five minute interval. This was at the transmitting end. At the other end the galvanometer was continuously in circuit while receiving and it deflected as strongly as though a battery was directly connected to

it, for each make and break of the sender.

After repeated success one way, conditions were reversed at a prearranged time of day, and the make and break made at the other station while the first station connected up to receive and did receive the signals. At the end of three hours the "upper electric body moved away" showing Loomis the need for going higher to reach "the atmospheric stratum or ocean overlying local disturbances."

On another occasion he writes, "The signals perfect during the *cloudy* part of the day" and this seems to have been between Cochoctus Mt. and Beorseden Mt., Va. In the sketch of this, Loomis shows as one idea, a buzzer interrupter and as an alternate construction between aerial and ground a spark gap in series with a coil. He speaks in the patent of "impulses," apparently recognizing their short duration. It is reasonable to believe that in making and breaking contact in the first experiments, with the coil of the galvanometer in series and the high tension of atmospheric electricity, there were sparks at the break which caused exactly the same phenomena as Hertz and Hughes and Dolbear and Marconi found long afterwards and, as the equipment at the receiving station was exactly the same as at the sending station, they

would be tuned alike and the response of one to the other would be a maximum.

On the sketch of Loomis the addition of any source of high tension across the spark gap would give a complete "modern" spark transmitter. Without this, with the gap adjusted to the potential he might have been able to obtain from the atmosphere, the action of the device anticipated Marconi by 25 years with a better apparatus.

Dr. Rogers of Hyattsville, the inventor of an underground radio system, said, "Dr. Loomis had the aerial, and he was the first one who had it. He sent up kites and hung copper wires on them. He also had the underground idea, and it was after talking with him that I started out to try to perfect the underground system of communication which I finally did and which assisted considerably in the late war." He says also that Loomis at times hung vertical wires from his kites.

Inspired, no doubt, by Morse's success in getting Congressional backing, Loomis applied to the Congress and after struggling with them from 1869 to 1873, a bill was passed incorporating the "Loomis Aerial Telegraph Co." but they did not appropriate the $50,000 asked for, completing in this way Loomis's long years of failure

to get backing. In 1869 he had interested Boston capitalists. Then came Black Friday and his backers lost everything. In 1871 he went to Chicago and interested capitalists there, but the great Chicago fire caused his new supporters to lose all.

It is pleasing to record the enthusiastic sarcasm with which the press received the idea of an aerial telegraph, regardless of the method by which it was to be accomplished.

The *New York World* on May 22, 1872 said:

> "Who will not be edified to know that the time of the House of Representatives was taken up for an hour or more Monday night by an elaborate oration by Mr. Conger of Michigan in support of a proposition for establishing an aerial telegraph."

Conger's speech was made May 21, 1872 and in it occurs the significant passage:

> "causing electrical vibrations, or waves, to pass around the world, as upon the surface of some quiet lake one wave circlet follows another."

The *N. Y. Journal of Commerce,* February 5, 1873, after referring to the passage of the

incorporation act by Congress, continues:

> "We will not record ourselves as disbelieving in the Aerial Telegraph, but wait meekly and see what the Doctor will do with his brilliant idea now that both Houses of Congress have passed a bill incorporating a company for him. Congressmen, at least, do not think him wholly visionary; and it is said that the President (Grant) will sign the bill; all of which is some evidence that air telegraphy has another side than the ridiculous."

The *Buffalo Express,* February 24, 1873, suggested:

> "It would be a fatal objection to the popularity of the system if people had to go to the top of Mt. Hood, Chimborazo, Popocatapetl, or to the crests of the Himalayas and Andes to send their dispatches."

Six years later the *Electrical Review* of London (March 1, 1879) reported "with telephones in this aerial circuit he (Loomis) can converse a distance of twenty miles," and the editor courteously indicated by means of the interrogation point that he didn't believe it. However, the

Hartford Times in 1878 had stated in its Washington letter that Loomis had succeeded in telephoning over this distance frequently—apparently the first mention of wireless telephony.

Apropos of the Loomis idea with respect to atmospheric voltages, we may note that Lord Kelvin found a potential increase on the island of Arran of as high as 46 volts per foot rise, increasing to ten times this on occasions. Joule and Kelvin at Aberdeen, says S. P. Thompson, found the rise of potential equal to 40 volts per foot. During fine weather the higher strata of air is always positive. Beccaria found it negative only six times in fifteen years and then with heavy winds.

Lord Kelvin was of the opinion that the upper regions of the atmosphere where the air is rarified conducts like rarified gases in a Geissler tube. The lower air is a non-conductor. The upper stratum being positive and the earth negative with an intervening stratum of dry, non-conducting air, forms a condenser or Leyden jar, which explains the gradual differing potential as one rises. Loomis himself had referred to the charged stratum and the ground being separated by a non-conducting stratum and had compared this with the Leyden jar.

In 1893 Nikola Tesla proposed to transmit

electrical oscillations any distance with similar apparatus and the press spoke of it as "marvelous research" but it has never been done by Mr. Tesla. The same inventor said in January, 1900, that he had a wireless that will "stagger humanity." He was convinced that soon he would be able to communicate with every city of the world at a speed of from fifteen hundred to two thousand words per minute (!) and the technical papers spoke about it seriously. Nobody laughed. Now he claims to have solved the problem of transmitting electrical power with slight loss by radio!

In spite of it all, Loomis never lost faith. Shortly before his death in 1886 he said to his brother:

> "My compensation is poverty, contempt, neglect, forgetfulness. In the distant future, when the possibilities of the discovery, as I see them, are more fully developed, public attention will be directed to its originator; and the congressional records will furnish the indisputable evidence that the credit belongs to me. But what good then?
>
> "Still, there is a present satisfaction in knowing that some time the proper credit will be given. In the meantime, others will reap the benefit in worldly wealth and worldly honors. Monuments will be reared

to their memory, costly monuments, in token of the world's appreciation of their genius. I ask but a rose-bush to mark my grave, affording a brief resting place for passing song-birds, and I have a feeling that I shall even then be conscious of their carolings."

II

The introduction of the telephone receiver in 1876 gave an instrument for recording electrical impulses far more sensitive than had ever been known. It has been calculated that the energy in the flame of an ordinary match burning for two seconds is sufficient to maintain an audible sound in a sensitive telephone receiver continuously for ten thousand years.

Soon after this device was available it was found that sounds were produced in the telephone by distant lightning flashes before the actual flash took place, showing that there was a near-by inductive effect. Faint sounds had been noticed hours before flashes were near enough to be visible.

In the course of telephone experience many similar strange inductive effects were noticed. In August and September, 1877, listeners in Providence, R. I., happened to hear concerts in Troy, N. Y., Saratoga, and Albany although

not connected in any way with those places. It was afterwards discovered that separate telegraph lines from each of these cities were strung on the same poles or adjacent poles throughout a stretch of some 16 miles. Then in Providence for a short stretch of less than 1000 feet, telephone and telegraph wires were parallel to each other. The signals no doubt passed by magnetic induction from wire to wire just as they do between the primary winding and the secondary winding of Faraday's transformer. The concerts, by the way, in the various cities were being broadcast over the telephone wires for the purpose of demonstrating a loud speaker to an audience in a distant hall. This was a frequent stunt in the early telephone days.

In 1877 Professor Sacher of Vienna studied this "cross talk" or inductive phenomena and found that a tiny current through one wire about a hundred yards long could be distinctly heard in a telephone receiver connected to another wire parallel to it and 75 feet away, there being no connection between the two wires. Professor Blake of Brown University talked over a telephone using the two railway tracks as the connections between stations and distinctly heard the Morse code passing along the wires strung overhead. And even before either of these events

a Dr. Channing of Providence, R. I., had isolated two parallel telegraph lines and using no batteries, connected his telephone transmitter with one wire while in a receiver on the other wire a listener could distinctly hear his speech, the infinitesimally small currents generated by the moving diaphragm of the transmitter being sufficient to induce currents large enough to actuate a telephone receiver in the other parallel wire, the only medium between them being the changing magnetic field. This was pure induction. It was the phenomenon seized upon by many searchers as the basis for a system of wireless.

Professor John Trowbridge of Harvard University about 1891, in a discussion of the induction method, devised the first directional signaling device corresponding, in a manner, to present radio compass station operation. He proposed, as a possible means of preventing ship collisions in a fog, that a wire be stretched back and forth from one cross-arm to another on a steamer's foremast, and connected with a powerful dynamo for sending or with a delicate telephone receiver for listening. If an approaching ship has a similar rig and one vessel is sending, the current being interrupted with great frequency, a musical note will be heard by any listener on the other ship, the sound being strongest

when the wires are parallel, i. e., when the ships are headed at each other. Thus one could keep away from the other.

Unfortunately for the future of this invention, Professor Trowbridge found, on calculation, that the size of the coil required for this effect at a half mile range would be enormous and, if the coil were made a reasonable size, the battery or dynamo would have to be enormous for those days. So this scheme was not considered practical until some method could be found to tune the coils, so to speak, so that the electrical oscillations in one might invoke sympathetic vibrations in the other, and Professor Oliver Lodge set himself to the task of finding a way to do this tuning! Thus he was ready to tell how to tune Marconi's system when the time came!

Some years previously—about 1880—this same Professor Trowbridge had devised a system of telegraphing across the Atlantic without a cable. There was little new about the details. Morse, for example, had a somewhat similar plan for short distances which an accident had prevented his trying between Governor's Island and Castle Garden back in 1842. In 1845 J. W. Wilkins of the Cooke & Wheatstone Telegraph Co. had proposed to signal between England

and France by the same method. Henry and Edward Highton had actually tried it for short distances and the former in 1872 mentioned the transatlantic possibility.

Trowbridge's idea was the erection of enormous dynamos in Nova Scotia with one end of the circuit grounded there and the other end grounded in Florida, the wire to the Florida end being carefully insulated and, of course, supported on poles all the way. Then when a current of high frequency (probably about 180 to 200 cycles) passing over the wire was interrupted with a Morse key, the signals sent along the line to Florida could be picked up on the way back by a sensitive telephone receiver on the French coast, the ends dipping into the water. The thought was that the current in the return ocean or ground circuit would not come back in a straight line but would spread out like the magnetic lines from the poles of a magnet, so that points in this electric circuit of different potential could be found almost anywhere on the Western face of the globe.

In theory, at least, some of the energy would return to Nova Scotia by way of France and England and any observer could tap in on this return path.

The papers did not ridicule him as they had

Mahlon Loomis but a few short years previously, for Trowbridge was a Professor at Harvard and, although his plan was quite the most fantastic ever seriously proposed by anybody, it is theoretically possible. It was about as practical as moving the Woolworth Building up to Times Square on a subway train.

Trowbridge suggested this same arrangement on a considerably smaller scale, to prevent ship collisions. The one terminal of the dynamo was to be at the bow of the steamer and the other at the end of a long insulated wire dragged over the stern and buoyed up by floats, only the tip end of the wire bare to make contact with the water. Thus each ship would be surrounded by a plane of electrical influence (like the field around a magnet) and any other ship coming into this field would pick up warning signals. This was about 1880.

Alexander Graham Bell carried out this latter plan experimentally and found that with the distance about 100 feet between the bow of the boat and the stern drag contact and with a battery of six cells, a telephone receiver on board a second boat a mile and a half away would record a musical note when the first current was rapidly interrupted. In *Public Opinion* of January 31, 1886 he urged all ships to become

equipped with this sort of device, over which not only warnings could be sent in fog and darkness but also voice communication carried on.

III

To return again to the induction schemes, Sir Wm. H. Preece and Mr. A. W. Heaviside with insulated wire formed into squares a quarter of a mile on a side, and laid horizontal, one arranged to transmit and the other to receive, sent signals in 1885 from one to the other by the inductive effects when they were 1000 yards apart. With telegraph lines parallel and ten miles apart a telephone in one was made to hear the signals passing in the other. Before 1886 similar effects were observed in lines forty miles apart.

This inductive scheme of communication at a distance to amount to anything was never found practical although it is a question whether in many of the experiments an approach was not made to wireless, the propagation of waves, rather than the purely magnetic phenomena which would, of course, accompany such propagation because a moving electric field would be accompanied by a magnetic field. In 1894, for example, Preece experimenting with a primary

and secondary coil far apart in an inductive signaling system such as described found that there was a decided maximum effect with one particular frequency "confirming," as he said, "the presence of resonance," a matter then in its infancy. Later Preece in the same year, stretched a wire on poles and with it entirely disconnected at the ends could pick up signals at a certain frequency of interruption of the current in the other wire parallel to it. He found that the distance of reception depended on height of the wire above the earth and depth of the ground plate below.

"As these waves are transmitted by the ether," he said, "they are independent of day or night, of fog, or snow, or rain, and therefore, if by any means a lighthouse can flash its indicating signals by electro-magnetic disturbances through space, ships could find out their positions in spite of darkness and of weather. Fog would lose one of its terrors, and electricity become a great life-saving agency." This was before Marconi appeared on the horizon.

In the same year (February 23, 1894) Preece said:

> "Strange mysterious sounds are heard on all long telephone lines when the earth is used as a return, especially in the calm

stillness of night. Earth currents are found in telegraph circuits and the aurora borealis lights up our Northern sky when the sun's photosphere is disturbed by spots. The sun's surface must at such times be violently disturbed by electrical storms and if oscillations are set up and radiated through space, in sympathy with those required to affect telephones, it is not a wild dream to say that we may hear on this earth a thunderstorm in the sun. (Compare M. Pupin's address in Philadelphia, December, 1926.)

"If any of the planets be populated with being like ourselves, having the gift of language and the knowledge to adapt the great forces of nature to their wants, then, if they could oscillate immense stores of electrical energy to and fro in telegraphic order, it would be possible for us to hold commune by telephone with the people of Mars."

This was thirty-three years ago, two years before Marconi's first wireless, and yet it has a modern flavor.

The use of inductive transmission for short distances was, of course, not new. Communication with a train in motion was almost as old a thought as the train itself and to do so inductively began with Mr. A. C. Brown in 1881 who suggested that a signal wire be strung along parallel with the rails, having a battery and key

in its circuit to provide signaling means. Then he suggested a coil of wire on the train as long as possible and in inductive relation to the signal wire, with a telephone receiver for the man on the engine to listen in for orders. If desired, a transmitter for voice could be used instead of a key for code. It was tried and found successful.

Willoughby-Smith in 1883 suggested an arrangement not far from what is now being considered in connection with railroad safety devices. He had a spiral receiving coil beneath the engine and any number of signal coils could be mounted between the tracks at whatever points seemed best. Then, as the train passed over any coil, the signal received would gradually increase to a maximum strength.

Two years later Edison and Gilliland patented a slight modification of the same scheme using a condenser plate on the car and static induction instead of magnetic induction, for no good reason at all. It was used on a Staten Island railroad and some others for a short time when it quietly disappeared. At the outset, however, Mr. Edison said (April, 1886):

"Railway business will be expedited to a degree undreamt of as things are, and the

> risk of accidents will be largely diminished. . . . Ships at sea, many miles apart, will be able to communicate by means of balloon kites (sic), soaring several hundred feet above their decks. . . . Regions now remote from telegraphs could be brought within the civilized circle by means of mountain or forest stations equipped with the new apparatus, etc., etc."

Here Edison with his kites and mountain stations was turning a leaf of Loomis's notebook, but nobody laughed.

Six years later under the exhilaration of a new patent on the same things with his balloon kites and mountains added, Mr. Edison is reported as having said that if a "sufficient elevation be obtained to overcome the curvature of the earth (sic) and to reduce as far as maybe the earth's absorption,—the method will be serviceable for signaling across oceans." This scheme, of course, differed from that of Loomis only as tweedledee differs from tweedledum but it was listened to in wrapt admiration.

IV

Between 1879 and 1886 Prof. Hughes of England made a series of remarkable researches and was prevented from publishing them

through papers to the Royal Society only by the discouraging advice of the President of the Society and the two secretaries, particularly Prof. Stokes, to the effect that all could be explained on the basis of induction. This marvelous mistake by Stokes was before Hertz, Branly or Marconi. When a careful investigation was made in 1899 Mr. J. Munro published a statement which includes: "Thus Prof. Hughes step by step put together all the principal elements of the wireless telegraph as we know it to-day and although he was groping in the dark before the light of Hertz arose, it is little short of magical that in a few months, even weeks, and by using the simplest means he thus forestalled the great Marconi advance by nearly twenty years."

Another student of Hughes' work has said, "Hughes' experiments of 1879 were virtually a discovery of Hertzian waves before Hertz, of the coherer before Branly and of wireless telegraphy before Marconi and others." Hughes died, highly honored, on January 22, 1900, at the age of 69 and before much progress had been made over what he had done himself, but what was done was better understood.

America can lay some claim to David Edward Hughes. Although born in London in 1831 his parents migrated to America when he was about

seven. Hughes became the Professor of Music and later of Natural Philosophy at the College in Bardstown, Kentucky. In 1854 he went to Louisville to manufacture a printing telegraph, patented in 1855, which became quite successful in the fight against the high rates of the Morse Company then in vogue. In 1857 he went to Europe to introduce his method there and in his native land he rose to eminence.

Not all of Hughes work had been kept from the public eye. He had given the world the microphone in 1878. On May 8, of that year Hughes in one of his papers had described the coherer, which Branly was to rediscover and Marconi to patent, as a tube with loose zinc and silver filings and plugs to contact with them. He called it a microphone tube. In 1884 Calzecchi-Onesti in Italy had devised the same thing using brass plugs and copper filings. Branly got the inspiration in 1890. Actually the daddy of them all, until Dr. Guthe in *London Electrician* traced the coherer back to Munk in 1835, was thought to be S. A. Varley who in 1866 had described a similar tube with metal plugs and for the loose contacts a mixture of carbon and a non-conductive powder such as sulphur.

The Italian Onesti arranged his tube to decohere on being rotated, anticipating Lodge's

tapping device. He also suggested the possibility of using the tube for detecting earthquakes, believing from experiments that the slightest jar would change its conductivity.

Hughes greatest discovery was that an interrupted current in any coil gave out at each interruption intense extra currents such as to fill the house and room with a momentary invisible charge evident to the observer if a microphone was used in series with a telephone. He thought of these as invisible waves and searched for a better detector. He found the waves permeated great distances and went through walls.

For his improved detector he used a coke microphone, (the first crystal detector) and also coke on bright steel. His loose contact microphone between metals was sensitive enough but it would cohere. Later he used voltaic cells in series with microphone and receiver.

To induce the waves, he found any sudden electrical impulses, whether with a spark coil or frictional machine, were effective. Even a spark from a rubbed piece of sealing wax gave results. The essential was a sudden high potential. When a coil was used, he found an iron core to be a hindrance which first showed him that the result was not an inductive effect. The action of the iron was to slow down the extra current or, as

we would say, the result was a much lower frequency. (Dr. E. W. Marchant in 1900 showed photographically that Hughes was right in this.) He received in the house and up and down the street as far as he walked, some 500 yards. He noticed certain points opposite houses where he could hear better, which puzzled him until 1887 when Hertz discovered nodal points in the reflected waves.

All of this was carefully recorded by Hughes at the time and attested by many noted witnesses but Hughes was so greatly discouraged by his failure to convince Sir George Stokes that he never published any of it to the day of his death, although opening his notes to others freely.

As Stokes misjudged the work of Hughes and so kept back the wheels of progress in England, so in America Professor A. E. Dolbear was misdirected by the judgment of Prof. Houston who told him his results were no doubt purely inductive. The trouble in both cases was that nothing else was known and while Hughes and Dolbear both had reason to visualize a new effect, the border line was very close until the brilliant work of Hertz. Dolbear in his patent of March, 1882, gives almost exactly Marconi's arrangement of ten years later.

He has a telephone transmitter on the primary

of an induction coil and the secondary connected to earth and elevated aerial condenser plate. At times he used a gilt kite for the aerial, *à la* Loomis. The receiver is connected to earth, aerial condenser plate and battery. First, for transmission he used a Morse key, through which a magneto was grounded, the other terminal of the magneto in free air and a foot or two long. At one time he used an induction coil with key and an automatic interrupter in the primary. This was in 1882. Dolbear attributed his results to "some ether action" and never did believe himself that it was inductive and it wasn't, in any of his apparatus as we know now.

V

Marconi's work is the great landmark in radio development. Nothing can detract from the importance of what was accomplished by him and in a real sense he may be called the "father," if not the "inventor" of wireless. Professor Slaby of Charlottenburg who had himself made progress in wireless before Marconi's name was known, said in April, 1898:

> "In the English professional journals an attempt has been made to deny novelty to the method of Marconi. It was urged that the production of Hertz rays, their radia-

tion through space, the construction of his electrical eye—all this was known before. True; all this had been known to me also, and yet I was never able to exceed one hundred meters."

Slaby was referring to the distance he could send a signal. Loomis, Hughes and Dolbear all exceeded Slaby's distance so his words mean nothing.

Sir Wm. Preece, whose own work has been briefly mentioned, had earlier said:

> "He (Marconi) has not discovered any new rays; his receiver is based on Branly's coherer. Columbus did not invent the egg, but he showed how to make it stand on its end, and Marconi has produced from known means a new electric eye more delicate than any known electrical instrument," etc., etc.

Actually what Marconi did is well described by the reference to Columbus. Marconi stood the oscillator of Hertz on its end! He put one plate in the air and one plate in the ground, with the spark gap in between. Thus most of the energy radiated, as we know now, was sent out along the surface of the earth instead of scattering in all directions as it does from a condenser system not earthed. This was the reason for his results

being more marked than any of the others who followed Hertz.

Marconi adapted the Hertzian research to the device of Loomis, Dolbear and Edison, although he may never have heard of their work which, of course, came before the flood light which Hertz shed over the whole field. Marconi's improvement was in practical application. His genius lay in continually driving ahead, always improving and striving for better results. For ten years his personality dominated radio.

Born in Bologna April 25, 1874, he studied at the Leghorn Technical School and followed the writings of Professor Righi of the University of Bologna. At 20 he was thoroughly acquainted with electric wave theory and started to experiment (June, 1895) on his father's estate near Bologna. He used the ordinary Hertz oscillator with an induction coil for energy supply. He is credited with first using one plate on the ground through having accidentally or incidentally laid it there to attend to something else, and then not noticing it. Be that as it may, he seized upon the advantage and observing that the higher the other plate was held, the greater the distance over which signals were sent, he erected taller and taller masts on the top of which he placed the plate, afterwards substi-

tuting a metal can or cylinder similar to what is shown in one of the Loomis sketches. He investigated carefully the relation between the height of the can and the distance transmitted and found that with twice the height, he could send four times the distance. This was the first law of wireless.

The cans finally became cubes about a foot on a side. The larger the cube the greater the distance covered. In 1896 he went to England, a modest Irish-Italian youth of 26, and on June 2 applied for a British patent, the equivalent American patent being 586,193 issued July 13, 1897 and reissued as 11,913 on June 4, 1901. In July, 1896 he secured the attention of Preece who a year later testified to Marconi's advance in the art of signaling without wires and thus drew the attention of the entire scientific world, for Preece himself had been one of the leaders in the quest up to that time.

At first the distance covered on land was but four miles and over the water was nine miles. For nearly three years public demonstrations took place in England and then in Italy where by July, 1897, twelve miles was covered between warships. Later, with a ten inch spark between two inch balls, up to fourteen miles was reached, masts 120 feet high having been employed to

support an insulated strip of wire netting held vertical. Marconi, in reply to a question, boldly predicted the possibility of sending twenty miles with apparatus properly constructed. By the end of 1898 space telegraphy was established as practical over short distances, especially from ship to shore, a field that nothing else had touched, if we except the "plane of influence" system of Trowbridge. Loomis had shown a sketch of the idea, however.

Not until 1899 did Marconi make any considerable change in his receiver. Then, in place of the coherer directly in the aerial-ground wire, he put it across the secondary coil of a transformer of which the primary coil was in the aerial line. Lodge had previously patented this idea (Brit. 11,575 of 1897) but gave no details of construction. At this time Marconi bridged the English channel (32 miles) after erecting masts on each side holding up 150 ft. vertical antennae of stranded copper wire. That feat aroused the press and, although scientific men refused to admit that it was an indication of utility, a ship collision happening to occur between an outward bound vessel and the Goodwin lightship in the channel, the latter boat having Marconi's equipment aboard was able to communicate instantly with the shore. Tugs

were immediately dispatched to the scene and saved many lives. Without their assistance the lightship would have unquestionably sunk. This was the first demonstration that such a system did mean much to the world, but established communication companies and banking systems still did everything possible to "pooh-pooh" the whole scheme.

Before 1897 Lodge had clearly recognized the necessity for "tuning" or providing a way in which the receiver could be attuned to the particular message desired and in that year he received the patent before mentioned (11,575), in which was revealed a tuning method. His tuning was largely accomplished by the shape and arrangement of the antenna and the addition of a coil to the spark gap circuit. Early in 1900 Marconi applied for a patent (Brit. 7777, April 26, 1900) to accomplish the same end. Then in a few years came Marconi's invention of the bent or directional antenna, something of the nature of the ones used now, a vertical down-lead or "lead-in" and a flat, horizontal top. This advanced matters by leaps and bounds.

In 1899 Marconi, leading up to the above successful directional method, had attempted to focus a beam of waves by a parabolic copper

mirror, reflecting the beam as Hertz had done with his short waves. Mr. S. G. Brown and Mr. Lee DeForest separately evolved several forms of reflectors at about the same time, the basis of their devices being spaced vertical wires or rods arranged in parabolic form instead of solid metal. But, while all these things worked, they were of no advantage for the long waves then in use. Now they are being revived for short wave use in linking up the British colonies by wireless. DeForest and Brown each proposed what is now called "loop" reception and transmission previous to 1901 but it was not then practical.

On December 12, 1901 Marconi at St. Johns, Newfoundland, heard three dots (code for the letter S) repeated over and over again as evidence that in far distant Wales signals were being sent across the Atlantic for the first time without wires, a Lodge antenna being used in sending and a Loomis kite aerial in receiving. He knew then that some day messages would be sent and they were, beginning a year later almost to the day (December 17, 1902). He could look back with a smile to October 7, 1898 when the *Investor's Review* stated, referring to the incorporation of a company to own Marconi's patents:

"From all we can gather the public will be well advised to keep clear of this concern—Signor Marconi's ingenious ideas do not seem to have made much headway, and it would be interesting to learn what the government officials reported about them."

CHAPTER XIII

ALADDIN LIGHTS A LAMP

"For who on things remote can fix his sight
That's always in a triumph or a fight?"

—COWLEY.

THERE was no orderly progress from the discoveries of Hertz to those of Marconi. Scientists seem to have seen no particular connection between the Hertzian philosophy and the practical problem of wire communication. Michael Pupin appears to have been the leader in that connection and his work applied to telephony gave substantial results. As for communication without wires, it was a case of cut and try after 1890 when Prof. Threlfall of Australia and in 1892 Sir Wm. Crookes both pointed out the possibility of Hertzian waves for telegraphy.

We have seen how Hertz himself was set on the right path by an accidental discovery of a means for detecting the presence of waves, his well known resonator. Marconi's detector was the Branly coherer and at the time his success

was erroneously laid to the sensitivity with which he constructed the coherer. But the use of the coherer as a detector was as much an incident as Hertz's resonator was an accident.

Branly in 1890 had finished his research. He had found, almost casually, that a spark at a distance sometimes increased the resistance of the filings and sometimes decreased it, depending upon the material or metal from which filings were obtained. He apparently gave no thought to the utility of the device. In 1892 Dr. Dawson Turner brought Branly's work to public attention and discussed it in connection with some of his own findings at a meeting of the British Association in Edinburgh. During this discussion Professor George Forbes asked whether it were not probable that this sort of a device might indicate the presence of Hertzian waves. The thought was a new one. Nobody knew the answer but in 1893 Prof. Minchin "distinctly said the change was due to electric radiation, and not to the light of the spark," says J. A. Fleming.

This is an amusing flareback to Joseph Henry's idea, mentioned before, to see if the lights of a spark from flint and steel gave him the same effects that he obtained from a Leyden jar discharge! However, even then the coherer

was not thought of as a detector for wireless signals. Lodge set this thought adrift in June, 1894, and gave the name "coherer" to Branly's device. Marconi picked on it for his use, made some changes in its details and secured a patent on it some years later which stirred up considerable controversy.

Professor A. S. Popoff of Russia came into the argument in 1896 and seems to have contributed the tapper, being the hammer of an electric bell in circuit with the coherer and a relay so that after the filings had cohered following the passage of a signal, the device would be agitated and ready for the next signal. Lodge had previously used various jarring devices, including a clockwork arrangement, and Calzecchi-Onesti, as said before, had arranged to rotate the device for decohering the powder.

Following the coherer there were hundreds of improved forms, some of them self regulating. Magnetic and electrolytic devices pushed forward and numerous contact arrangements modeled more or less after the Hughes microphone. All were temporary until the production of the Fleming tube about 1905 to be followed two years later by the three element tube of Lee DeForest, called by him the audion. This is the tube now used wherever radio is known.

Fleming's tube comprised an evacuated glass bulb or "envelope" in which, at first, were sealed two carbon filaments but later only one filament was used and, in place of the second filament, a metal plate was made to surround the lone filament, a connection from this plate being brought out from the bulb. It had been found that with the filament incandescent, an electric current could pass through the tube from plate to filament in that direction when the plate was connected to the positive side of a battery, the filament being connected to the negative end. No current would pass, however, when the connections were reversed. That is to say, the tube was conductive only in one direction. It was a one way valve and the word "valve" came to denote such a vacuum tube and is so accepted to this day in Europe. The Fleming valve is now used as a rectifier for battery chargers and eliminators but is no longer used in reception.

DeForest's contribution was a slight addition to Fleming's tube but in that slight addition the whole future of radio lay. He inserted a terminal or "grid" between the filament and the plate so that the passage of current between these terminals could be controlled by the slightest electrification of the grid. This changed the action of the device completely. It made the

tube an amplifier, as well as a detector, of radio waves, and in doing so produced one of the finest pieces of electrical apparatus the world has ever seen. While it is far from perfect for radio purposes, it is such an amazing improvement over anything yet suggested as to justify the feeling that the future will see its principles retained, regardless of what changes may be made in its physical construction.

The basis of both the Fleming valve and the DeForest vacuum tube is the emission of electrons from hot bodies. Negative particles of electricity are shot out into the air from any flame or incandescent solids such as carbon or metals. Probably the sun sends out enormous numbers into our atmosphere, as J. J. Thompson points out. It makes no difference how the body is heated but the material of the surface and the temperature both affect the number of electrons shot out.

Dr. A. Wehnelt, a German physician, in April, 1904, made public his remarkable discoveries on the effect of coating filaments with the oxides of barium, calcium, and strontium to immensely increase their electron emission. Even a fragment of lime on a strip of incandescent platinum will do. These coatings, known as Wehnelt coatings, have been used in many

vacuum tubes. In this country the WD tubes were of this construction, making it possible with even a faintly glowing platinum filament to obtain sufficient electron emission for radio receiving. This sort of construction for the Fleming tube was first described in 1911 by R. S. Willows and S. E. Hill. The trouble with it has been non-uniformity, the difficulty of evacuating properly with the coating present, but many improvements have been made by independent inventors and there is a tendency back to this type of filament, especially in A.C. tubes.

The high emission from tungsten filaments as used in other vacuum tubes, is due to a similar surface action from a coating which forms of itself on the filament. It was early found that a pure tungsten filament was not desirable in electric lamps because of "offsetting" or "sideslip," a localized weakening of the filament wire when used on alternating current. The introduction of a small amount of thorium seemed to cure the defect, due to a difference in crystallization that took place. When this type of filament came to be used in vacuum tubes on direct current where there is no sideslip manifest, the thoriated tungsten of common lamp use gave much higher emission than other forms and the cause was traced to the thorium which, although

added to the tungsten as an oxide, sort of boils out and spreads over the surface of the filament as the thorium metal, giving it a highly emissive coating which can be more or less renewed from within, if evaporated off.

Thus such a tube is "rejuvenated" sometimes, after having been almost ruined by excessive filament voltage or too high a plate voltage.

The emission of such a filament is, however, greater than either tungsten or thorium gives alone and is even greater than their sum. There must be, therefore, an interaction between the metals, possibly a thermoelectric effect or positive polarization of the thorium layer which pulls the electrons through the surface separating the two metals, at a terrifically high speed. A similar action is found when a thin layer of gas surfaces an electron emitting body.

To trace the background of the tube we can look back to that experiment of the burgomaster of Magdeburg who found the flame of a candle caused the charge to leak off the feather whereupon the feather, hitherto repelled, flew back to the sulphur globe. This was electron emission from the candle flame and, strangely enough, DeForest early in his work made a "tube" with a flame instead of a filament, although not with that idea in mind.

Coming down from Von Guericke, we may pause at Dufay who noticed in 1725 that a conductive path for electricity was formed between a hot sphere and a cold one. In 1746 the English scientist Watson, in 1745 the Frenchman Du Tour, in 1767 Priestley, in 1785 Cavallo, Coulomb and many, many others noticed a similar effect. Canton in 1762 wrote in the *Philosophical Transactions* of that year, "Let the end of a poker when red hot be brought but for a moment within three or four inches of a small electrified body, and its electrical power will be almost, if not entirely, destroyed." Matteucci in 1850 proved the leakage was less under low pressures.

Edison in 1884 showed that this phenomenon is very apparent when a carbon filament is heated to incandescence in a rarified gas, or a vacuum. Becquerel in 1853 found that air heated to 1500 degrees C. was conductive and in 1881 and 1887 Blondlot confirmed this. Schuster had early shown that a discharge through gases is a process resembling that of electrolysis. F. Guthrie in 1873 had found that at red heat an insulated iron ball could retain a charge of negative electricity (recalling Dufay's red hot coals!) but not a charge of positive. At white heat it would retain neither.

In 1880 Elster and Geitel confirmed Guthrie's experiments. They used a filament of either carbon or wire and a separate metal plate in a vessel which could be exhausted or have various gases admitted. Generally speaking, their conclusion was that a metallic wire gave off positive electricity (This is short lived and probably due to occluded gas) at or below red heat and negative at higher temperatures. Carbon gave off negative electricity at all temperatures. In 1889 they mention the unilateral conductivity of the tube with one electrode hot and the other one cold.

Fleming began experimenting with the phenomenon in 1883 after noticing how the carbon of a filament is projected to the walls of the lamp making the glass black. Preece began in 1884 when Edison gave him some lamps with plates in them. W. Hittorf in that year recorded the conductivity of an evacuated bulb in which there was an incandescent filament. In 1896 Fleming found a platinum filament very hot gave the same effect qualitatively as a carbon filament. Sir W. Grove had previously found a current set up in a platinum wire one end of which touches the tip and the other the base of a flame.

There was a perfect muddle of experiments

and not until 1897, when J. J. Thomson published his researches on the conductivity of gases, were these phenomena thoroughly understood to be due to electron emission and then Fleming, recalling his early work and needing a one way valve for use in wireless, tried out the device after unsuccessfully attempting to use an aluminum rectifier for the purpose. He secured a patent on the valve, which immediately became tangled up in litigation.

The carbon lamp itself was old at that time, of course. In 1835 J. B. Lindsay invented a light which "burned steadily in open air or in a glass tube without air" when supplied with current from a galvanic battery. In 1841 a lamp using a platinum filament was invented by Demoleyns. In 1845 carbon was used for the filament by Mr. Starr of Cincinnati, and to prevent combustion he put it in an exhausted glass vessel. These all dropped out of sight for a while because of the lack of electric power, but later the Starr-King lamps became very well known.

There were no commercial power houses then.

In 1873 a Russian named Alexander de Lodyguine investigated the subject and won the prize of the St. Petersburg Academy of Sciences for his paper showing the great advantages of carbon filaments in glow lamps over any other ma-

terial. The same man has many U. S. patents including one for a tungsten filament dated 1897, much earlier than any of those under which tungsten lamps were manufactured. He was then in America.

In 1879 Edison made a carbon filament lamp using brown paper as his carbon source. A year later he used bamboo, while just before his work Swan in England was making lamps with filaments made of carbonized cotton parchment. The reason the Edison patent was held valid over Sawyer & Man and other previous inventors was that Edison made his filaments 1-64 of an inch in diameter which was half the diameter of theirs and of greater resistance compared with its surface. This was technically a new invention.

The first assault on the supremacy of carbon as a filament was made by Von Welsbach in the late nineties by the production of osmium pure enough to be made into wire. Tantalum soon followed and tungsten lamps made their appearance abroad but were slow in reaching America. Platinum lamps had long been known, of course, and zirconium, iridium and other metals of the same high melting points had been tried from time to time. Failure of refractory metals, other than tungsten, at the high temperature neces-

sary for economy, has usually been due to their tendency to volatilize and blacken the bulb.

And we must not close this brief summary of the detectors used for wireless without noting that long after both Fleming valves and DeForest audions were known, Dr. Lefeuvre of the University of Rennes, in France, used frogs' legs as detectors of radio current. In fact he made his receiver a recording device, the contraction of the frog's muscle as the current from the antenna is passed through the nerve moving a lever which makes the dots and dashes on a paper drum.

It seems to be ordained that frogs' legs will be used for something or other throughout eternity.

CHAPTER XIV

LIBERTY THROWS HER SHOULDERS BACK

"Exhalations whizzing in the air."
—SHAKESPEARE, *Julius Cæsar* I:2

IMMEDIATELY following Marconi's success with wave telegraphy serious attempts were made to apply the same principles to wave telephony or the wireless telephone, now called radio. First experimenters tried merely to substitute a telephone microphone for the key or interrupter. This did not work out so well although A. F. Collins seems to have had a little success with a modified method but the discovery of the singing or speaking arc by Simon in 1898 and Duddell in 1900 gave a means by which telephony was established.

The problem, though not then fully realized, was the same as had confronted Reis and Bell with the wire telephone. In those early days making and breaking the circuit sent a telegraph signal, a long connection for a "dash" and a short one for a "dot." Transmission of speech involved

something more, however, as each sound is itself complex, made up of a multitude of air vibrations all of which must be preserved. Some audible sounds are notes comprised of as many as 20,000 to 30,000 vibrations a second and, of course, it is hopeless to try and break a circuit as rapidly as that and at the same time to vary the rate of breaking the circuit even during that period as would be necessary, because sound changes are themselves instantaneously variable.

In the wire telephone the solution was found in varying the resistance of the circuit, which is a mechanical problem, rather than in breaking the contact which would be a complex electrical problem. The reason for this is that breaking the contact requires a definite time because of the resulting spark which is an oscillatory discharge of a period depending upon the electrical nature of the circuit, as was first deduced by Von Helmholtz in 1847, mathematically demonstrated in 1853 by Lord Kelvin and experimentally verified by Fedderson in 1859. If the spark can be sustained, continually oscillating and sending out wireless waves just as if a telegraphic key were rapidly operated, any voice vibration can be made to alter that continuous, regular oscillation, introducing irregularities into it. This process is called the voice modula-

tion of the wireless waves, and the continuous wave sent out is called the carrier wave.

The singing arc lamp of Duddell gave just that continuous regular oscillation at a frequency of about 10,000 per second. Mr. V. Poulsen of Denmark improved the arc in 1903 and raised the possible maximum frequency to well over 100,000 per second, by using a cooled metal electrode and an atmosphere of hydrocarbon gas. It was necessary to get the frequency higher than any audible frequency in order that only the change in frequency due to the voice would be heard.

With such an arc actuating the spark gap, the current variation in the arc was itself regulated by the microphone, which limited the current that could be used because the microphone would otherwise burn out. This current limitation fixed the maximum distance of voice transmission at 200 or 300 miles, even when a cooling system was hooked up for water to circulate through the microphone and cool the carbon granules.

Many ingenious arrangements were devised to overcome this trouble but the beginnings of present day methods came when R. A. Fessenden in a series of experiments from 1901 to 1905 had done away with the arc by the invention of

a very high frequency alternator (dynamo) reaching 75,000 to 100,000 cycles per second. This required no spark gap in the aerial circuit but was itself connected thereto with proper coils and condensers to give a natural frequency of vibration of the antenna system equal to the alternator frequency and thus send out waves of that period. The microphone was inserted in the aerial-ground circuit. With this arrangement Fessenden sent speech between Brant Rock and a steamer some 12 or 15 miles away, in December, 1906, and at the same time communicated with Plymouth, Massachusetts (11 miles). Later a distance of 200 miles was achieved.

Only a few months before the Brant Rock experiment Mr. Edison in reply to a question "What is the outlook for wireless telephony?" gave the answer "It does not exist."

Improvements in high frequency alternators were made by Béthenod, R. Goldschmidt and E. F. W. Alexanderson after Fessenden had shown the way. But DeForest's invention of the amplifying tube revolutionized the outlook for wireless telephony almost at once, and in 9 years from the time of the Brant Rock experiments the transmitting distance had been raised by its use to 4700 miles when from Arlington, Va.,

on September 30, 1915, voice traveled through the ether to Honolulu and to Paris on a wave-length of 6000 metres (frequency 50,000 cycles per second).

To the general public the radio telephone is most familiar in its use for broadcasting which was first started by Lee DeForest from the top of the old Parker Bldg., N. Y. City, in the summer of 1907 while he was testing out wireless telephone transmitters for installation on Admiral "Bob" Evans' battleships and destroyers prior to the famous round-the-world cruise. DeForest at that time having no artists, used phonograph records and many must have been the ship operators who rubbed their eyes with amazement when out of the ether they heard voices and music mixed with the international code! It has been recorded that more than once the golden voice of Caruso sailed out across the waves to a very limited audience.

Regular broadcasting as now known also is due to DeForest who in March, 1920, installed a transmitter in the California Theater at San Francisco for the transmission of concerts by the symphony orchestra there, a total of 1500 such concerts having been sent out from that one station. In November, 1920, the Westinghouse Co. went on the air from WJZ, perhaps the first

popular broadcasting on an organized commercial scale.

Broadcasting was not a modern idea, however. We have seen how back in 1877 concerts were broadcast over telephone wires and in 1898 Sir Oliver Lodge had said of wireless "It might be advantageous to shout the message, spreading it broadcast to receivers in all directions, for which the wireless system is well adapted" because it was inexpensive and easily installed. And he specifies that it would be desirable for the purpose of following the day's happenings "such as army maneuvers, for reporting races and other sporting events and, generally, for all important matters occurring beyond the range of the permanent lines."

But even now, with hundreds of stations and a toll service across the Atlantic, we cannot look forward with confidence to attaining the point prophesied by W. E. Ayrton many years ago when he said:

> "The day will come, when we are all forgotten, when copper wires, guttapercha covers and iron bands are only to be found in museums, that a person who wishes to speak to a friend but does not know where he is, will call with an electrical voice which will be heard only by him who has a sim-

ilarly tuned electrical ear. He will cry, 'Where are you?' and the answer will sound in his ear, 'I am in the depth of a mine, on the summit of the Andes, or on the broad ocean.' Or perhaps no voice will reply, and he will know that his friend is dead."

CHAPTER XV

THE RED BADGE OF COURAGE

"Greater love hath no man than this—"

St. John, xv:13

THE "CQD" of the *Republic* and of the *Titanic* will always be remembered. On one the wireless call brought rescue to all but six. On the other, though many were saved, the lost numbered 1,517, including the heroic Phillips, chief wireless operator.

But there are many souls whose ships have sailed into the Great Beyond. When the jazz of Broadway strikes up from station WHN, picture that other WHN, the good ship *Hanalei* dashed to pieces outside the Golden Gate! Station WGR to you may spell Buffalo but to the old time operator it means the steamer *Governor* and disaster in the cold waters of Alaska.

When the soft, southern voice of WSB floats northwards from the cotton fields of Georgia, remember the *Francis H. Leggett* sinking off the coast of Oregon with eighty souls on board, the wireless operator sticking to his key. Station

WRW is now at Tarrytown, but once it was the *F. A. Kilbourne,* gone to glory in the Caribbean. To listeners in Detroit WWI means Ford, but down around the shipping offices of the Pacific Mail it is still the flaming *Pennsylvania,* a torch alone on the vast waters of the sea.

And so it goes. Each call letter is a story of the heroism of some wireless "ham."

This, too, is part of the background of Radio.

NAME INDEX

ELECTRICAL INDEX

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